Appendix F.2

Evaluation of Historical Flow and Salinity Measurements of the Lower San Joaquin River and Southern Delta

Section F.2
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F.2.1 Introduction

This appendix describes and evaluates the measured flow and salinity (electrical conductivity [EC]) patterns along the Lower San Joaquin River (LSJR) and in the southern Delta for 1984–2011. The data are summarized as monthly values, and a more detailed review of the daily flow and EC data from four relatively dry (i.e., low flow) years (2000–2003) is provided to better understand the relationships between flow and salinity in the LSJR. Daily flow and EC measurements provide the most accurate picture of the seasonal patterns of the various flows (e.g., tributaries and groundwater seepage) and the likely sources of relatively high salinity water that control the San Joaquin River SJR salinity at Vernalis and downstream in the southern Delta. The daily salt loads, which are proportional to the flow times the EC, are described for various locations along the SJR.

The evaluation of monthly data from 1984–2011 also allows the likely effects of changes in the existing conditions that might be expected with near-future changes in water management (e.g., Upper SJR Restoration Program) and salinity management (e.g., SJR Improvement Project implementation for the selenium Total Maximum Daily Load) within the SJR watershed to be generally considered (i.e., cumulative effects on future baseline conditions).

The standard measurement of salinity in rivers is EC. As salinity increases, the EC across a 1 centimeter (cm) electrode gap will increase. Devices have been developed that measure this electrical current for a constant voltage potential and adjust for the temperature of the water. EC measurements are generally adjusted to a temperature of 25°C. The calibration of field devices is achieved by comparing meter readings when the electrode is immersed in water standards prepared by dissolving a known quantity of salt in water.

The range of EC within the Delta is 100 µS/cm (freshwater) to more than 25,000 µS/cm (about 50 percent seawater).[1] Because each station is independently calibrated, EC station measurements on the same day (assumed to be measuring the same river water) may not be exactly the same. An EC variation of 25 µS/cm is often observed between adjacent stations. This can be used as an estimate of EC measurement accuracy.

Salinity is generally "conservative," meaning the mass of salts is neither increased nor reduced by chemical reactions (i.e., dissolving or precipitating) within the river. The river concentration of salt will be increased by the addition of salt (e.g., high salinity water) or by evaporation of some of the water. The river load of salt is the mass of salt in the river per time (e.g., day or month). The daily salt load can be calculated from daily flow and EC values as:

$$\text{Salt load (tons/day)} = 5.4 \times \text{flow (cfs)} \times \text{EC } (\mu\text{S/cm}) / (1.54 \times 2{,}000) = 0.00175 \times \text{flow} \times \text{EC}$$

Where 1.54 is the assumed conversion between 1 milligram per liter (mg/L) of salt and 1 µS/cm of EC [0.65 mg/L = 1 µS/cm], and 5.4 is the conversion between 1 cubic foot per second (cfs) and 1 mg/L to 1 pound per day [1 cfs *x* mg/L = 5.4 lb/day].

[1] The analysis in Appendix F.1, *Hydrologic and Water Quality Modeling,* and Appendix F.2, *Evaluation of Historical Flow and Salinity Measurements of the Lower San Joaquin River and Southern Delta*, describes salinity (EC) in terms of microSiemens per cm (uS/cm). Chapter 5, *Surface Hydrology and Water Quality*, primarily describes salinity in terms of deciSiemens dS/m. The conversion is 1 dS/m = 1000 µS/cm.

The river salt load (mass/time) will increase substantially with the addition of relatively high salinity water from agricultural drainage or wastewater discharge, and will increase slightly with the addition of relatively low salinity water such as the eastside tributaries or with rainfall (rainfall EC is less than 25 µS/cm). The salt load of the river does not change with evaporation because the salt concentration will increase as the water evaporates. The salt load of irrigation water does not usually change with evaporation and crop transpiration; the salt concentration in the soil and in the drainage water increases as water evaporates.

The effects of increased SJR flow on EC can be generally described as a dilution response; higher flows (runoff or reservoir releases) will reduce the salinity of the river and add only slightly to the salt load. The monthly salt loads are not constant however, so predicting the monthly EC of the SJR above the Merced River or at Vernalis from the monthly flow alone will not be completely accurate. By understanding sources of salt within the SJR watershed (salt loads), the ability to determine expected salinity above the Merced River or at Vernalis will be improved. From this framework, likely effects of changes in the tributary flows with alternative flow objectives, and the likely effects of alternative salinity objectives at Vernalis, can be accurately evaluated.

An earlier model of the SJR flow and salinity was developed by Charlie Kratzer and Les Grober, while they worked for the State Water Board in 1987. The model was called the SJR Input-Output (SJRIO) model (Kratzer et al. 1987). The SJRIO modeling report remains the most comprehensive review of water budget and salinity budget information for the lower SJR. This model used one-mile segments to account for flow (inflows and diversions) and salinity along the 60 miles from the Lander Avenue Bridge (i.e., Highway 165, Stevinson gage) to the Airport Way Bridge (i.e., Vernalis gage). The SJRIO study period was 1977 through 1985, prior to any continuous EC measurements.

The SJR landscape can be summarized with the SJR miles for some major inflows and flow (or EC) measurement stations as the following.

- Stevinson gage (Lander Ave, Highway 165 bridge) at SJR mile 132.
- Salt Slough at SJR mile 129.
- Fremont Ford gage at SJR mile 125.
- Mud Slough at SJR mile 121.
- Newman Wasteway (from the Delta-Mendota Canal to the SJR) at SJR mile 119.
- Merced River at SJR mile 118.
- Newman gage (Hills Ferry Bridge) at SJR mile 117.
- Orestimba Creek at SJR mile 109.
- Crows Landing gage at SJR mile 108.
- Patterson gage at SJR mile 99.
- Patterson Irrigation District (ID) pumping-plant canal at SJR 98.
- Del Puerto Creek at SJR mile 93.
- West Stanislaus ID pumping-plant canal at SJR mile 85.
- Tuolumne River at SJR mile 84.

- Maze gage at SJR mile 77.
- Stanislaus River at SJR mile 75.
- Vernalis at SJR mile 72.
- Banta–Carbona pumping-plant canal (fish screen) at SJR mile 63.
- Mossdale gage at SJR mile 57.
- Head of Old River at SJR mile 53.

There are several inflows and several diversions along the river that influence the flows and EC along the SJR. The three tributary rivers provide a majority of the flows, but westside streams and agricultural drainage and groundwater seepage to the river provide the majority of the salinity (salt load). Two major inflows upstream of the Merced River are Salt Slough and Mud Slough, which drain agricultural lands (tile drainage) and wildlife refuge wetlands and duck clubs on the west side of the SJR (e.g., Grasslands Water District). The Merced River enters just upstream of the Newman gage and 10 miles upstream of the Crows Landing gage. Orestimba Creek enters from the coastal mountains at SJR mile 109, just upstream of the Crows Landing gage. The Patterson main canal and pumping plant is downstream of the Patterson gage at SJR mile 98. Del Puerto Creek enters from the west at SJR mile 93. The West Stanislaus Irrigation District main canal pumping plant is at SJR mile 85, just upstream of the Tuolumne River mouth at SJR mile 84. Hospital and Ingram Creeks join with their mouth at SJR mile 83. The Maze Road Bridge is upstream of the Stanislaus River mouth. The Vernalis gage is at SJR mile 72. The Banta–Carbona Irrigation District main canal and pumping plant is at SJR mile 63. Much of the Banta–Carbona Irrigation District lands have tile drainage systems; drainage water from the tile drainage systems enters the SJR just downstream of the diversion canal.

F.2.2 Monthly Flows EC and Salt Loads for the SJR

Daily data for these SJR and tributary streams were averaged as monthly values, to provide a summary of seasonal flow and salinity conditions in the SJR, from upstream of the Merced River to Vernalis. Although there are many flow and EC monitoring stations operated by the California Department of Water Resources (DWR) and United States Geological Survey (USGS) along the SJR and tributaries, there are incomplete records at many stations; some interpretation of available data is required to identify seasonal and flow-related patterns.

The historical monthly flow and EC data are summarized in tables for each station giving the cumulative distribution of monthly flow for the available data (1985–2011). The monthly data are summarized with the minimum value and in 10 percent cumulative distribution increments, (e.g., 10^{th} percentile, 20^{th} percentile, 30^{th} percentile, etc.) up to the maximum value, along with the average monthly value. These tables show the historical range and distribution of flow and EC values. The unimpaired flows (estimated flows without diversions or storage) for the entire period of record, 1922–2010, are given for each watershed. The comparison of unimpaired flows with recent historical flow data indicates the general degree of water resources development (storage and diversions) within each basin.

F.2.2.1 Comparison of Unimpaired and Historical SJR Flows

Table F.2-1a shows the monthly cumulative distribution of SJR unimpaired runoff (cfs) at Friant Dam for 1922–2003 (CALSIM 82-year analysis period). The range of monthly runoff is summarized with 10th percentile values from the minimum to the maximum. The median (50th percentile) monthly values provide a good summary of the seasonal pattern. The maximum runoff was in April, May, and June. The minimum runoff was in September, October, and November. The range of flows from year-to-year is large. The annual runoff ranged from less than 803 thousand acre-feet (TAF) (10th percentile) to about 3,044 TAF (90th percentile). The average annual runoff for the SJR at Friant Dam was 1,732 TAF, representing about 28 percent of the SJR unimpaired flow at Vernalis. The median runoff was 1,453 TAF.

Table F.2-1a. Monthly Cumulative Distribution of SJR Unimpaired Flow (cfs) at Friant Dam for WY 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	81	95	121	161	204	305	957	1,216	587	260	150	75	362
10%	115	171	237	296	541	1,079	2,134	3,400	2,029	667	233	127	803
20%	157	223	267	384	760	1,353	2,583	3,907	2,487	754	282	169	936
30%	171	257	345	535	956	1,545	2,889	5,063	3,552	920	363	194	1,128
40%	206	290	508	632	1,111	1,731	3,399	6,084	4,675	1,462	440	226	1,250
50%	266	354	584	768	1,340	1,925	3,966	6,916	5,430	1,868	556	259	1,453
60%	301	436	723	1,105	1,800	2,146	4,194	7,560	6,209	2,365	701	312	1,856
70%	338	546	894	1,332	2,050	2,614	4,693	8,283	8,052	2,968	840	382	2,048
80%	389	706	1,187	1,833	2,889	3,334	5,194	9,677	9,793	4,319	1,191	551	2,410
90%	544	1,101	1,892	2,743	3,741	3,773	5,879	11,456	10,789	5,982	2,056	699	3,044
maximum	2,048	4,151	7,489	11,953	8,506	7,895	10,300	17,826	19,597	12,225	4,558	2,853	4,642
average	315	563	969	1,351	1,837	2,342	3,978	7,043	6,275	2,736	850	404	1,732

Table F.2-1b shows the monthly cumulative distribution of historical (observed) flow below Friant Dam (cfs) for 1985–2009 (recent 25-year period). The median monthly flow values provide a good summary of the seasonal release pattern. The highest median flows of 200 cfs are in June, July, and August. The highest historical flows (90th percentile) were greater than 2,000 cfs in February–June, indicating that flood control releases were made in a few years in each of these months. The 90th percentile flows in April and May were greater than 4,500 cfs. The 80th percentile flows in March, April, and May were greater than 1,000 cfs. The monthly ranges of historical flows below Friant Dam were large only in months with flood control releases. The historical average annual flow volume released from Friant Dam was about 400 TAF. The median annual flow volume was about 130 TAF, indicating that the flood releases in a few years raised the average flow volume below Friant Dam to about 3 times the median flow.

Table F.2-1b. Monthly Cumulative Distribution of SJR Historical Flow (cfs) below Friant Dam for WY 1922–2009

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	61	56	36	32	39	36	97	121	136	150	124	114	64
10%	107	73	58	39	67	88	107	126	153	172	152	132	81
20%	124	96	78	58	78	92	119	144	182	198	191	157	103
30%	146	107	93	85	87	109	139	158	194	209	199	173	114
40%	155	118	97	94	95	119	144	165	244	219	208	183	121
50%	158	120	103	96	100	137	156	181	281	232	232	189	132
60%	160	125	104	100	110	174	192	218	301	260	245	219	161
70%	174	133	110	111	127	422	253	262	345	281	261	237	302
80%	190	147	117	118	457	1,004	1,258	1,016	637	573	278	251	766
90%	215	173	164	203	2,260	2,076	4,652	4,672	2,946	739	318	292	1,305
maximum	357	378	1,147	9,144	6,514	6,548	7,367	7,637	6,535	5,322	464	383	1,657
average	165	129	156	468	674	802	1,172	1,172	973	659	239	209	411

Table F.2-1c shows the monthly cumulative distribution of Merced River unimpaired runoff (cfs) at New Exchequer Dam for 1922–2003. The maximum runoff was in April, May, and June. The minimum runoff was in August, September, October, and November. The annual runoff ranged from less than 412 TAF (10th percentile) to about 1,718 TAF (90th percentile). The average annual runoff for the Merced River was 960 TAF, representing about 16 percent of the unimpaired SJR flow at Vernalis. The median runoff was 894 TAF.

Table F.2-1c. Monthly Cumulative Distributions of Merced River Unimpaired Flow (cfs) for 1922–2003

	Merced River Unimpaired Runoff (cfs) for Water Years 1922–2003												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	8	20	17	54	55	131	519	637	212	62	-	-	150
10%	23	59	89	162	337	601	1,352	1,650	741	129	27	-	412
20%	33	86	129	214	461	851	1,562	2,179	870	191	42	4	498
30%	46	102	167	326	579	970	1,927	2,832	1,400	292	63	22	566
40%	63	126	256	377	801	1,102	2,155	3,295	1,923	416	83	34	669
50%	81	152	354	571	969	1,303	2,391	3,955	2,451	529	121	58	894
60%	96	222	448	763	1,235	1,518	2,667	4,332	2,868	721	183	79	1,070
70%	116	302	560	1,069	1,821	1,875	2,880	4,730	3,462	842	221	102	1,158
80%	159	372	862	1,500	2,578	2,489	3,246	5,223	4,403	1,344	273	133	1,412
90%	255	699	1,647	2,579	3,514	2,718	3,643	6,400	5,633	1,991	514	203	1,718
maximum	835	4,346	6,058	10,306	6,295	6,013	7,206	9,194	11,025	5,719	1,578	798	2,787
average	115	335	703	1,073	1,496	1,643	2,473	3,932	2,875	909	208	93	960

Table F.2-1d shows the monthly cumulative distribution of historical (observed) Merced River flow (cfs) at Stevinson (downstream of Dry Creek) for 1985–2009 (recent 25-year period). The average unimpaired flow for this 25-year period was 937 TAF (98 percent of the 1922–2003 average). The highest median flows were in April and May, which are the months with highest unimpaired runoff.

The highest historical Merced River flows (90th percentile) were greater than 1,500 in February–June, indicating that flood control releases were made in a few years in each of these months. The 90th percentile flows in March, April, and May were greater than 2,500 cfs. The 80th percentile flows in March, April, and May were greater than 1,500 cfs. The monthly ranges of historical Merced River flows were large only in months with flood control releases. The median flows in the summer months of July–September were less than 150 cfs. The historical average annual flow volume for the Merced River at Stevinson was 438 TAF, about 47 percent of the average unimpaired flow for this period. The median annual flow volume was 267 TAF, indicating that flood releases in a few years raised the average flow volume in the Merced River to about 1.5 times the median flow.

Table F.2-1d. Monthly Cumulative Distribution of Historical Merced River Flow (cfs) at Stevinson for 1985–2009

	Historical Merced River Flow (cfs) at Stevinson for Water Years 1985–2009												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	32	131	171	129	69	166	136	91	25	6	18	25	73
10%	75	183	199	205	218	236	167	139	104	34	30	45	102
20%	159	231	218	226	243	250	183	191	126	59	65	78	140
30%	263	246	227	242	269	272	307	313	156	97	88	95	193
40%	298	248	236	259	312	285	357	647	180	125	100	114	220
50%	325	254	255	318	323	313	449	669	192	136	125	127	267
60%	374	271	293	421	351	363	622	734	257	178	145	186	324
70%	440	329	385	563	453	1,047	985	857	377	210	163	211	476
80%	526	423	473	697	933	2,360	1,425	1,409	609	321	313	371	703
90%	914	568	631	826	1,605	2,733	2,868	2,628	2,200	840	645	720	1,185
maximum	1,861	635	2,019	7,347	6,990	2,964	4,616	4,113	3,185	2,456	722	1,127	1,275
average	435	316	410	754	912	969	1,019	1,013	599	361	215	259	438

Table F.2-1e gives the monthly cumulative distribution of Tuolumne River unimpaired flows for 1922–2003. The peak runoff for the Tuolumne River is in May and June, and relatively high runoff (median monthly runoff greater than 2,000 cfs) is from February–June. The minimum flows are observed in August, September, and October. The annual unimpaired runoff ranged from 842 TAF (10th percentile) to 3,109 TAF (90th percentile), with a median runoff of 1,776 TAF. The average unimpaired flow was 1,853 TAF/year, slightly more than the median runoff. The average Tuolumne River runoff represents about 30 percent of unimpaired flow at Vernalis. Because about 290 TAF/year is diverted (to San Francisco) upstream of New Don Pedro Reservoir, the average inflow to New Don Pedro is about 1,563 TAF/year (85 percent of Tuolumne River unimpaired flow).

Table F.2-1e. Monthly Cumulative Distributions of Tuolumne River Unimpaired Flow (cfs) for 1922–2003

	Tuolumne River Unimpaired Runoff (cfs) for Water Years 1922–2003												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	-	21	55	81	142	379	1,326	1,724	283	166	-	-	383
10%	64	134	219	359	752	1,354	2,719	3,467	1,509	283	52	19	842
20%	87	150	332	529	1,046	1,881	3,136	4,730	2,280	364	104	42	1,055
30%	116	239	423	685	1,216	2,093	3,706	5,620	3,708	559	153	63	1,189
40%	149	284	550	887	1,514	2,358	4,144	6,162	4,850	919	212	85	1,414
50%	178	382	783	1,213	2,085	2,566	4,498	7,343	5,648	1,119	289	125	1,776
60%	193	564	920	1,715	2,496	2,870	4,927	8,071	6,722	1,781	359	165	2,024
70%	254	804	1,322	2,130	2,924	3,449	5,366	8,744	7,468	2,329	447	221	2,176
80%	329	1,153	1,774	2,818	4,034	4,163	5,809	9,355	8,923	3,114	563	294	2,516
90%	609	1,636	3,562	4,224	5,360	5,511	6,473	10,710	10,040	4,942	901	374	3,109
maximum	2,486	8,765	10,565	16,806	10,718	9,411	11,097	15,617	17,077	10,598	3,337	1,745	4,631
average	265	807	1,441	2,020	2,586	3,088	4,601	7,258	5,913	2,012	432	205	1,853

Table F.2-1f gives the monthly cumulative distribution (range) of historical flows in the Tuolumne River at Modesto for the recent period of 1984–2009. The average unimpaired flow for this 25-year period was 1,823 TAF (98 percent of the 1922–2003 average). The average monthly historical flows were about 500 cfs in summer and fall (July–December) and were 1,000 cfs to 2,000 cfs in winter and spring (January–June). The 10th percentile historical flows were greater than 200 cfs from November through May and were about 100 cfs in other months. The annual historical Tuolumne River flow volume ranged from 155 TAF (10th percentile) to 2,273 TAF (90th percentile). The median historical annual river flow was 361 TAF. The average annual historical flow was 811 TAF, more than 2.25 times the median, suggesting that the majority of historical flow was the result of flood control releases in wet years. The average historical flow was about 45 percent of the average unimpaired flow, but the majority of this historical flow was in wet years with flood control releases. New Don Pedro Reservoir allows considerable carryover storage from one year to the next. Although flood control releases are not necessary every year, it is difficult to anticipate when reservoir releases for flood control storage will be required. The LSJR alternatives will generally increase releases in February–June and thereby reduce flood control releases in wet years.

Table F.2-1f. Monthly Cumulative Distribution of Historical Tuolumne River Flow (cfs) at Modesto for 1985–2009

	Monthly Cumulative Distribution of Tuolumne River Flow (cfs) at Modesto for Water Years 1985–2009												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	135	162	176	154	166	239	271	144	104	97	97	111	134
10%	166	204	193	205	243	260	362	274	115	109	120	121	155
20%	233	227	237	287	266	288	389	412	143	134	142	167	202
30%	251	254	253	369	418	301	538	465	210	198	190	185	264
40%	337	294	314	462	458	353	683	604	248	241	241	222	303
50%	408	317	408	543	474	742	752	734	255	253	264	256	361
60%	579	445	429	643	1,373	1,113	1,006	871	386	330	357	422	550
70%	629	472	457	834	2,467	3,589	1,788	1,359	479	353	444	514	1,112
80%	728	494	745	1,396	3,163	4,746	3,402	2,943	981	503	556	689	1,440
90%	1,098	544	1,765	2,262	5,371	5,524	5,512	4,556	4,262	1,769	996	974	2,273
maximum	1,794	1,212	4,996	15,498	8,782	6,182	8,264	7,964	5,481	3,291	1,437	2,365	2,399
average	542	414	735	1,453	1,964	2,041	1,971	1,752	1,047	602	422	498	811

Table F.2-1g gives the monthly cumulative distribution of Stanislaus River unimpaired flows for 1922–2003. Each month has a range of runoff depending on rainfall and accumulated snowpack. The median (50^{th} percentile) monthly flows generally characterize the seasonal runoff pattern. The peak runoff for the Stanislaus River is in May and June, and relatively high runoff (median monthly runoff greater than 1,000 cfs) is from February–June. The lowest median flows of about 150 cfs are in August, September, and October. The annual unimpaired runoff ranged from 467 TAF (10^{th} percentile) to 1,921 TAF (90^{th} percentile), with a median runoff of 1,088 TAF. The average unimpaired flow was 1,120 TAF/year, only slightly more than the median runoff. The average Stanislaus River runoff represents about 18 percent of average unimpaired flow at Vernalis.

Table F.2-1g. Monthly Cumulative Distributions of Stanislaus River Unimpaired Flow (cfs) for 1922–2003

	Stanislaus River Unimpaired Runoff (cfs) for Water Years 1922–2003												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	-	35	56	47	25	218	586	723	190	-	-	-	155
10%	48	95	146	218	398	827	1,683	1,634	681	107	33	16	467
20%	70	125	189	301	576	1,142	2,108	2,637	978	213	60	37	593
30%	90	155	217	400	781	1,326	2,509	3,020	1,629	308	92	57	680
40%	107	170	310	512	954	1,569	2,900	3,807	2,105	426	111	68	892
50%	128	229	399	664	1,251	1,704	3,247	4,657	2,757	556	152	80	1,088
60%	155	288	515	923	1,759	2,023	3,485	5,236	3,215	814	180	89	1,250
70%	175	381	726	1,402	1,884	2,304	3,868	5,781	3,664	1,029	222	115	1,356
80%	195	520	951	1,895	2,339	2,622	4,274	6,361	4,184	1,368	302	162	1,570
90%	253	804	2,028	2,940	3,417	3,802	4,631	7,153	5,572	1,810	425	216	1,921
maximum	1,438	6,155	6,704	10,724	9,250	6,742	7,271	9,675	10,627	4,659	1,246	643	2,952
average	157	463	858	1,322	1,685	2,076	3,226	4,585	2,953	867	203	112	1,120

Table F.2-1h gives the monthly cumulative distribution (range) of historical flows in the Stanislaus River at Ripon for the recent period of 1984–2009. The average unimpaired flow for this 25-year period was 1,081 TAF (97 percent of the 1922–2003 average). The Stanislaus release flow requirements have generally increased during this period. The average monthly historical flows were about 500–600 cfs in summer and fall (July–December) and about 850–1,250 cfs from January–June. The 10th percentile historical flows were between 250 cfs and 500 cfs in all months. The annual historical Stanislaus River flow volume ranged from 309 TAF (10th percentile) to 1,172 TAF (90th percentile). The median historical annual river flow was 421 TAF. The average annual historical flow was 584 TAF, about 1.5 times the median flow, suggesting that a few years had substantial flood control releases. The average historical flow was about 52 percent of the average unimpaired flow, but the majority of this historical flow was in a few wet years with flood control releases. New Melones Reservoir allows considerable carryover storage from one year to the next. Although flood control releases are not necessary every year, it is difficult to anticipate when reservoir releases for flood control storage will be required. The LSJR alternatives will generally increase releases in February–June and thereby reduce flood control releases in wet years.

Table F.2-1h. Monthly Cumulative Distribution of Historical Stanislaus River Flow (cfs) at Ripon for 1985–2009

	Monthly Cumulative Distribution of Stanislaus River Flow (cfs) at Ripon for Water Years 1985–2009												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	251	218	179	168	183	260	251	349	218	262	215	207	191
10%	323	290	222	194	220	308	507	532	464	339	305	273	309
20%	339	312	262	240	297	381	595	742	578	408	327	304	330
30%	391	317	304	313	312	501	742	841	591	434	356	316	344
40%	434	322	316	378	349	643	813	877	609	480	368	325	384
50%	479	373	341	404	435	854	902	1,091	712	502	404	369	421
60%	505	392	402	458	623	1,013	976	1,302	848	560	417	416	480
70%	556	414	442	614	850	1,138	1,112	1,424	1,016	654	522	458	607
80%	613	428	817	1,064	1,510	2,250	1,299	1,506	1,176	743	657	490	798
90%	819	627	943	1,508	2,824	2,980	1,850	1,592	1,312	1,099	1,197	978	1,172
maximum	1,951	962	3,194	6,273	6,499	4,887	4,537	4,130	1,867	1,876	1,792	1,702	1,537
average	579	409	559	898	1,111	1,291	1,102	1,205	843	631	559	497	584

Table F.2-1i gives the monthly cumulative distribution of the SJR at Vernalis unimpaired flows for 1922–2003. Each month has a range of runoff depending on seasonal rainfall and accumulated snowpack. The median (50th percentile) monthly flows generally characterize the seasonal runoff pattern and are largely the sum of the unimpaired runoff from the four sub-basins draining the Sierra Nevada described above. The peak runoff for the SJR at Vernalis is in May, with relatively high median monthly runoff (> 15,000 cfs) in April, May, and June. The lowest median flows of about 500 cfs are in September and October. The annual unimpaired runoff ranged from 2,565 TAF (10th percentile) to 11,035 TAF (90th percentile), with a median runoff of 5,804 TAF. The average unimpaired flow was 6,176 TAF/year, only slightly more than the median runoff. The majority of the average SJR at Vernalis runoff originated above Friant Dam and the three tributary river dams. About 500 TAF (8 percent) of the Vernalis flow was from the westside creeks and the valley floor watersheds below the four major storage dams.

Table F.2-1i. Monthly Cumulative Distributions of SJR Unimpaired Flow (cfs) at Vernalis for 1922–2003

	SJR Unimpaired Runoff (cfs) at Vernalis for Water Years 1922–2003												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	135	226	270	370	469	1,065	3,421	4,332	1,271	596	179	119	1,060
10%	266	482	756	1,090	2,203	4,328	8,453	10,196	5,050	1,248	390	228	2,565
20%	402	679	961	1,631	3,242	5,925	9,345	13,532	6,683	1,558	556	298	3,294
30%	472	799	1,191	2,174	4,063	6,502	11,451	16,697	10,444	2,167	705	349	3,626
40%	573	875	1,687	2,771	4,846	7,239	13,180	19,843	13,957	3,397	821	449	4,372
50%	611	1,141	2,264	3,544	6,294	8,227	15,205	23,054	16,240	4,044	1,095	528	5,804
60%	771	1,607	3,037	5,522	8,656	9,940	16,063	26,775	19,258	5,671	1,475	631	6,471
70%	919	2,118	4,004	6,582	10,908	11,608	18,291	28,163	23,256	7,338	1,746	767	7,370
80%	1,093	3,163	5,635	10,125	15,598	15,808	19,438	31,439	27,828	10,359	2,165	1,102	8,745
90%	1,433	4,567	10,127	16,209	22,086	18,631	24,588	39,962	34,832	15,453	3,969	1,409	11,035
maximum	6,937	25,787	35,970	61,733	41,703	42,337	43,320	57,955	63,738	34,979	11,891	5,812	18,978
average	889	2,346	4,557	6,880	9,459	10,839	15,639	23,881	18,722	6,728	1,720	832	6,176

Table F.2-1j gives the monthly cumulative distribution (range) of the historical SJR flows observed at Vernalis for the recent period of 1984–2009. The average unimpaired flow for this 25-year period was 5,964 TAF (97 percent of the 1922–2003 average). The release flow requirements on the three tributary rivers have generally increased during this period. The average monthly historical flows were about 2,000–2,500 cfs in summer and fall (July–December) and were about 4,000–6,000 cfs from January–June. The 10^{th} percentile historical flows were between 750 cfs and 1,500 cfs in all months. The annual historical SJR at Vernalis flow volume ranged from 886 TAF (10^{th} percentile) to 6,644 TAF (90^{th} percentile). The median historical annual SJR flow volume at Vernalis was 1,707 TAF. The average annual historical SJR at Vernalis flow volume was 2,777 TAF, about 1.5 times the median flow, suggesting that a few years had substantial flood control releases. The average historical SJR flow at Vernalis was about 46 percent of the average unimpaired flow for this 25-year period, but the majority of this historical flow was observed in a few wet years with flood control releases.

Table F.2-1j. Monthly Cumulative Distribution of Historical SJR Flow (cfs) at Vernalis for 1985–2009

	Monthly Cumulative Distribution of Historical SJR Flow (cfs) at Vernalis for Water Years 1985–2009												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	788	956	895	816	758	1,422	1,168	892	481	447	483	574	656
10%	1,047	1,125	1,040	1,160	1,375	1,768	1,457	1,480	1,059	709	712	872	886
20%	1,343	1,285	1,292	1,437	1,789	2,097	1,905	1,968	1,115	1,110	980	939	1,144
30%	1,435	1,565	1,405	1,816	2,008	2,196	2,262	2,141	1,435	1,163	1,118	1,132	1,259
40%	1,734	1,685	1,548	2,106	2,175	2,429	2,545	2,638	1,660	1,306	1,236	1,335	1,385
50%	2,003	1,759	1,688	2,319	2,534	2,736	2,751	2,755	1,748	1,400	1,557	1,452	1,707
60%	2,567	2,004	2,085	2,500	3,152	3,421	3,173	3,560	2,157	1,682	1,913	1,970	1,928
70%	2,703	2,146	2,231	3,784	6,227	8,279	4,956	4,808	2,747	2,055	2,027	2,145	3,448
80%	3,181	2,528	2,587	4,625	7,796	12,285	8,012	8,490	4,238	2,624	2,604	2,484	4,206
90%	3,836	2,771	4,081	5,582	11,607	14,887	19,796	14,933	12,398	4,990	3,491	3,835	6,644
maximum	6,153	3,290	12,192	30,377	35,057	25,035	27,937	26,055	17,760	13,193	5,442	5,758	8,588
average	2,396	1,904	2,435	4,131	6,144	6,594	6,355	5,804	3,951	2,514	1,845	1,956	2,777

F.2.2.2 Historical Patterns of SJR Flow and Salinity

The salinity of runoff from Sierra Nevada watersheds is relatively low. Although rainfall has an EC of less than 25 μS/cm, water released from Millerton Lake (Friant Dam) and the major tributary reservoirs has a measured EC of about 25–75 μS/cm. The EC measurements below each major dam indicate that salinity of the runoff is constant and does not change substantially between dry years and wet years. The only daily EC data measured below the reservoirs is the station at Friant, with measurements beginning in 2004. Grab samples from below the tributary reservoirs generally indicate similar range of EC values. The EC generally increases downstream in the SJR and tributary rivers because of agricultural drainage and groundwater discharge to the river, with relatively high EC. The increase in EC is generally greater when river flow is low. Near the confluence with the SJR, the measured monthly EC in the Merced River (at Stevinson) ranged from about 50–400 μS/cm; the measured monthly EC in the Tuolumne River (at Modesto) ranged from about 50–300 μS/cm; the measured monthly EC in the Stanislaus River (at Ripon) ranged from about 75–150 μS/cm.

Figure F.2-1a shows the historical monthly flows at stations upstream of the Merced River. The SJR flows upstream of the Merced River can be estimated by subtracting the Merced River flow from the SJR at Newman flow (just downstream of the Merced River). The estimated SJR flow above the Merced River is dominated by flood-control releases from Friant Dam and local runoff in a few months during wet years.

In most years, the SJR flows at Stevinson are very low (25–50 cfs), with EC values of 1,000–2,000 μS/cm in the last 10 years; higher EC values were measured in the 1990–1992 drought period. These low SJR flows originate from Bear Creek and local agricultural drainage (irrigation return) flows during summer.

Downstream of Stevinson, the combined flows from Salt and Mud Sloughs contribute a relatively constant flow of about 250–500 cfs, with a Salt Slough EC of about 1,000–2,000 μS/cm since 1996 when the Grasslands Bypass project separated the high selenium drainage (with high EC) from Salt Slough. The Mud Slough EC, which now contains most of the high selenium and high EC drainage, has an EC of 1,000–4,000 μS/cm. The Fremont flow and EC (just upstream of Mud Slough) can be combined with the Mud Slough flow and EC to provide an estimate of the SJR flow and EC upstream of Merced River; these monthly estimates generally range from 1,500–2,500 μS/cm from 1986–1989 and 2002-2011, years when measurement data are available to make the estimates.

Figure F.2-1b shows the calculated monthly salt loads for the SJR upstream of the Merced River, estimated as the Fremont salt load plus the Mud Slough Salt load. Another estimate of the SJR upstream of the Merced River flow and salt loads was provided by subtracting the Merced River flow and EC from the SJR at Newman flow and EC (just downstream of the Merced River). These estimates did not always match. The Salt and Mud Slough combined salt loads are also shown on the graph because this was the majority of the flow and salt load during low flow conditions. These salt loads, shown with the SJR monthly flows, generally ranged from about 25,000 tons/month to 75,000 tons/month. The salt loads were sometimes greater than 100,000 tons/month in high flow months, but the EC in these months was relatively low (less than 1,000 μS/cm). There was considerable variation in the monthly flow and EC values and the corresponding salt loads upstream of the Merced River. This is a very important flow and salt measurement location, and every effort should be made to obtain consistent and accurate flow, EC, and salt load estimates for the SJR above the Merced River. The salinity along the SJR and at Vernalis will largely be controlled by the flow and salinity upstream of the Merced River. EC data at the SJR Fremont, Mud Slough, Merced at Stevinson, and SJR Newman stations would allow replicate estimates of the flow, EC, and salt load.

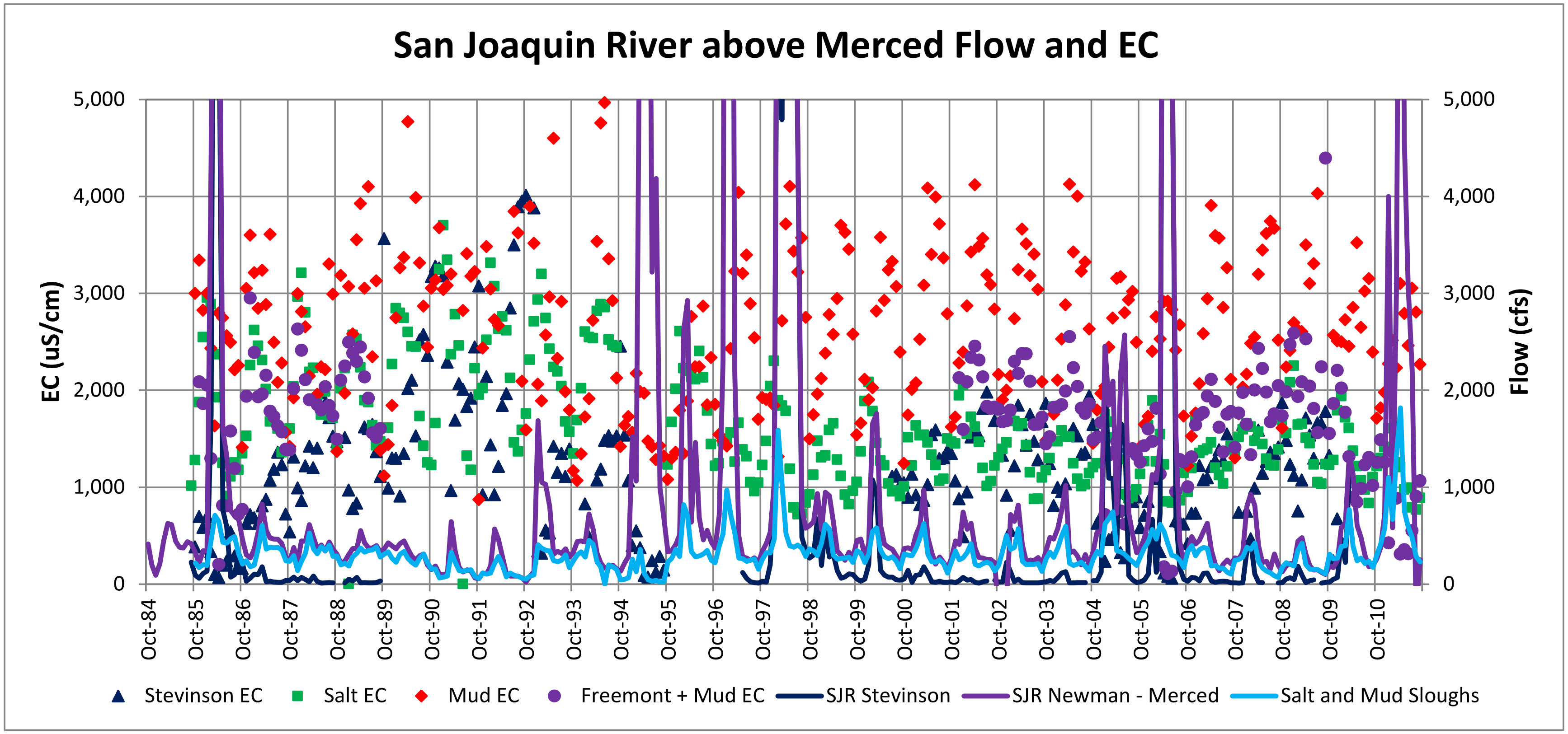


Figure F.2-1a. Historical Monthly Flow and EC in the San Joaquin River Upstream of the Merced River for WY 1985–2011

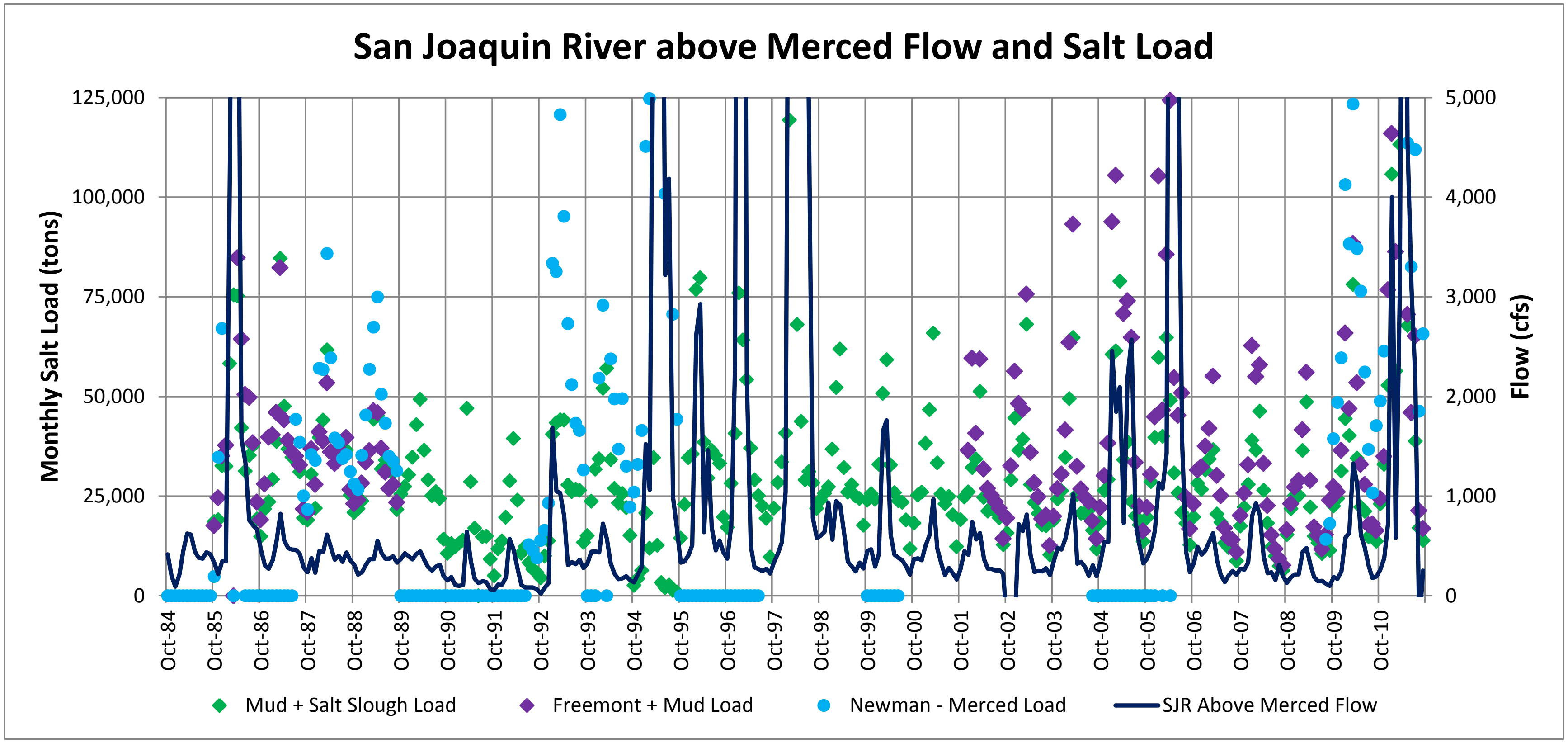


Figure F.2-1b. Historical Monthly Flow and Salt Load in the San Joaquin River Upstream of the Merced River for WY 1985–2011

Figure F.2-1c shows the Merced River flow and EC upstream at Cressy and downstream at Stevinson. The tributary river gains are an important part of the tributary water balance. The river flow generally increases between the upstream reservoir release and the mouth because of runoff (local streams), groundwater seepage, and irrigation return flow (some of which enters the rivers as shallow groundwater). There may be local riparian diversions that reduce the flow during the irrigation season. The volume and EC of these local inflows affect the EC in the river.

The Merced River EC upstream at Cressy was less than 100 µS/cm. EC increased along the length of the river, but was still relatively low at Stevinson (less than 400 µS/cm). For the Merced River, the data indicate that accretions between Cressy and Stevinson generally increased with higher flow (e.g., in association with local runoff). However, the EC at Stevinson tended to be higher at lower flows, when accretions were low or negative (Figure F.2-1d). This trend indicates that the increase in EC along the length of the Merced River is probably caused by a relatively small volume of salty inflow (e.g., agricultural drainage). Despite the longitudinal increase in EC along the length of the Merced River, EC at the downstream end of the Merced River at Stevinson (50-400 µS/cm) was still well below the EC in the SJR upstream of the Merced River (estimated as 1,500 to 2,500 µS/cm as described above), and, therefore, helped to reduce EC in the LSJR.

Figure F.2-1e shows the historical monthly flow and EC at stations downstream of the Merced River. The SJR flows at Newman generally ranged from 250 cfs–1,000 cfs, with lower flows in the dry years and flows of more than 5,000 cfs in wet years. The flows measured at Crows Landing and at Patterson were very similar to the Newman flows. The EC measurements at these three stations between the Merced and Tuolumne Rivers were generally similar, usually ranging from 1,000–1,500 µS/cm but with higher values of 1,500–2,000 µS/cm in the dry years of 1988–1994, and EC values of less than 500 µS/cm during high flows of more than 5,000 cfs.

Figure F.2-1f shows the historical monthly flows and salt loads downstream of the Merced River. The SJR salt loads at Newman, Crows Landing, and Patterson have been measured in different periods with limited overlap; the seasonal pattern is variable and the longitudinal pattern (increase or decrease) is difficult to discern from this graph. As indicated above, the SJR EC in this reach varies from 1,000–1,500 µS/cm in most months, so the monthly salt load generally follows the seasonal flows (i.e., highest in spring, lowest in summer). Because the monthly flows are 500–1,500 cfs in years without major storm flows, the monthly salt loads vary from about 25,000–75,000 tons. The majority of the salt load appears to originate from upstream of the Merced River, although the data suggest a moderate contribution between the Merced River and the Tuolumne River, perhaps from shallow groundwater and agricultural drainage.

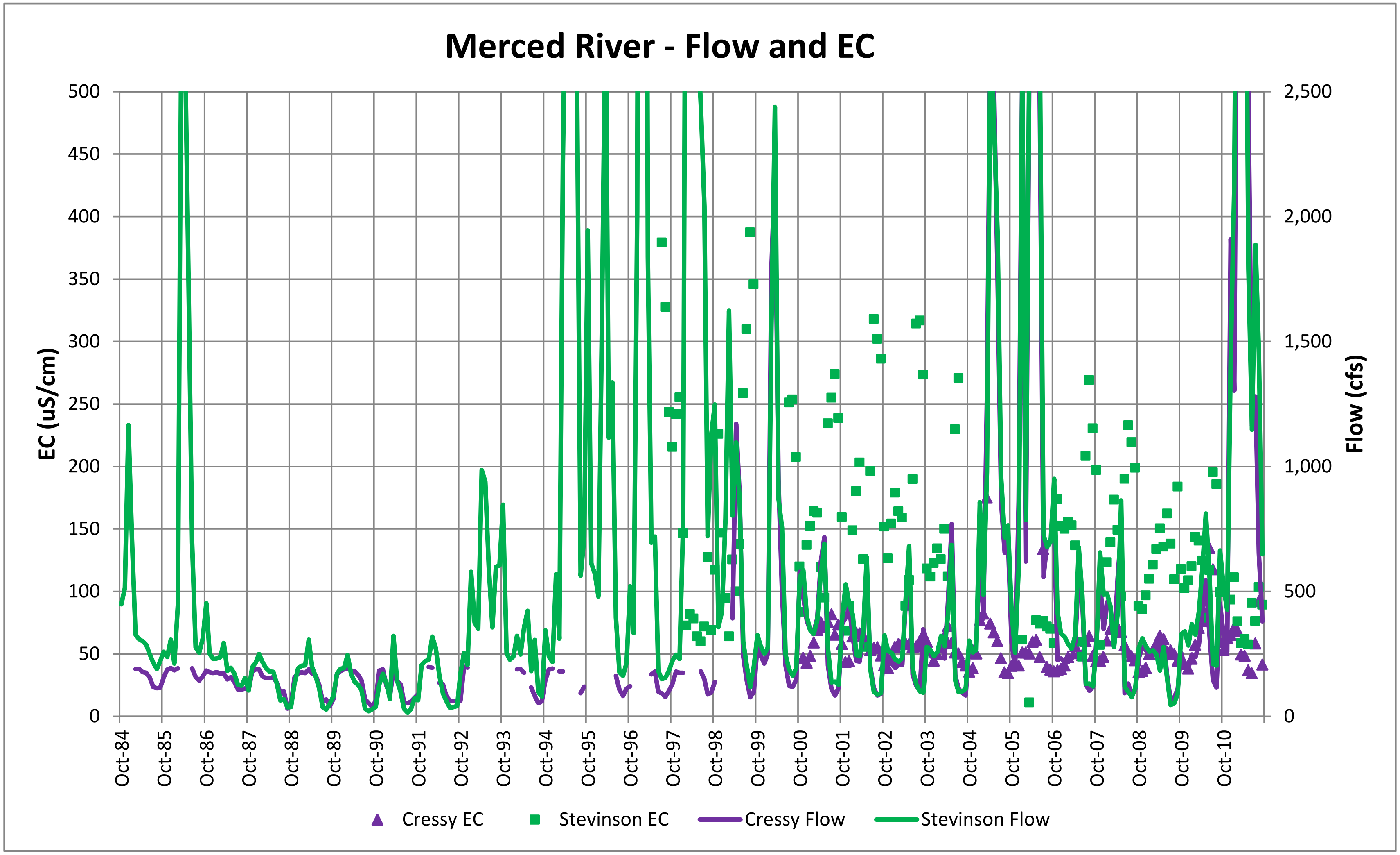


Figure F.2-1c. Time Series of Historical Monthly Flow and EC in the Merced River for WY 1985–2011

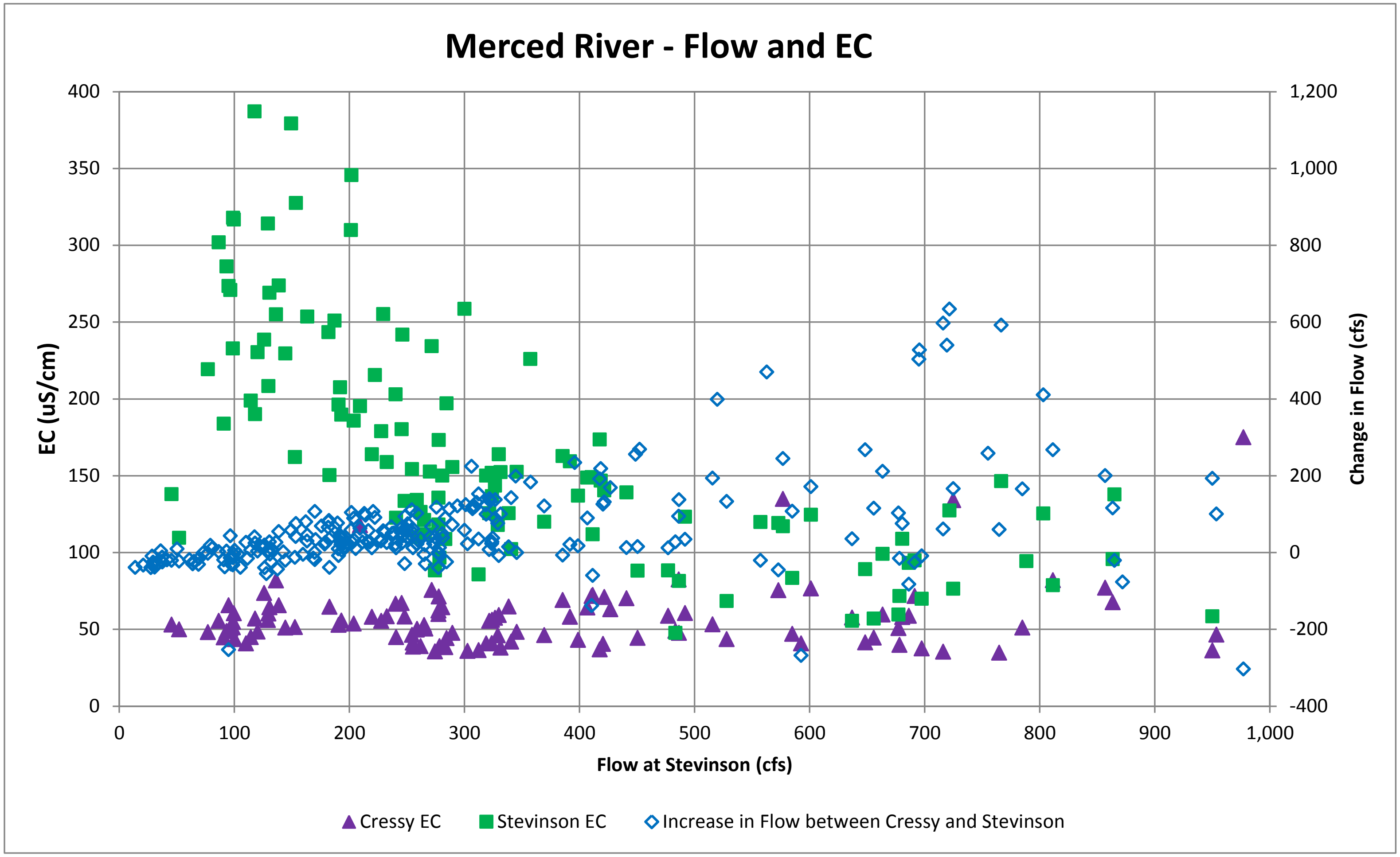


Figure F.2-1d. Relationship between Monthly Merced River Flow, Accretions, and EC for WY 1985–2011

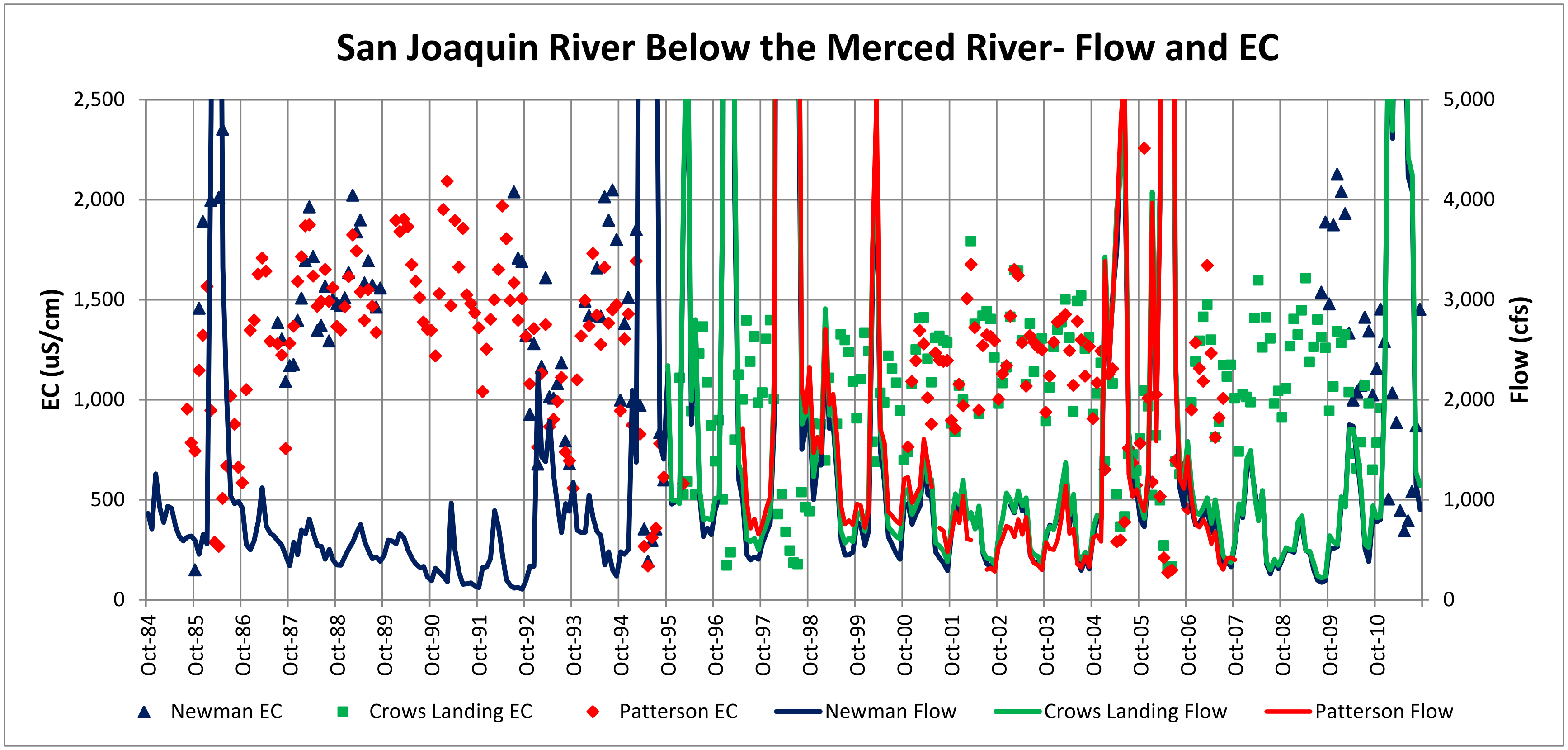


Figure F.2-1e. Historical Monthly Flow and EC in the San Joaquin River Downstream of the Merced River for WY 1985–2011

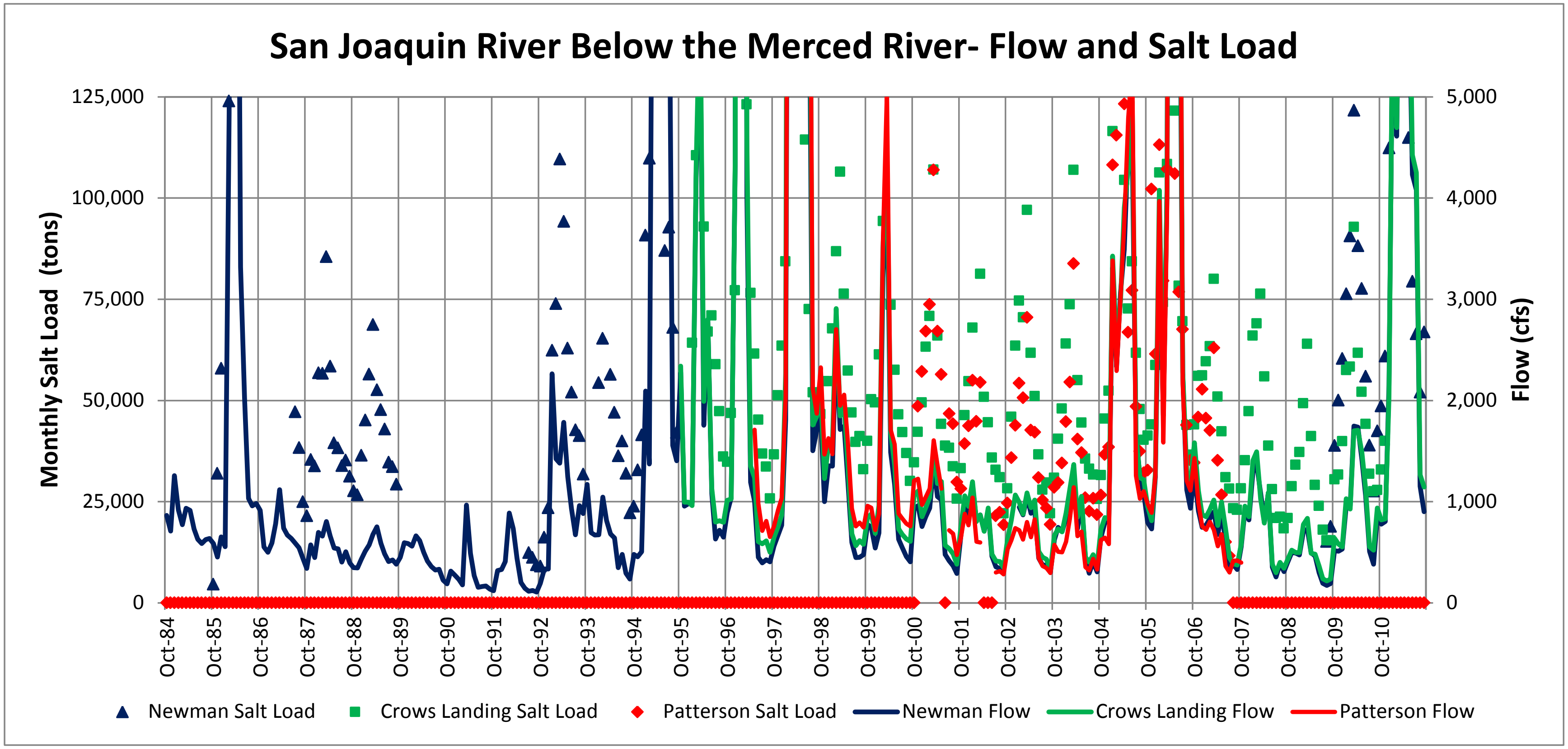


Figure F.2-1f. Historical Monthly Flow and Salt Load in the San Joaquin River Downstream of the Merced River for WY 1985–2011

Figure F.2-1g shows the Tuolumne River EC near the downstream end at Modesto as well as flow at Modesto and upstream at La Grange. Time series data for EC at La Grange is unavailable, but it is likely that EC along the Tuolumne River increases in a manner similar to the Merced River. The data indicate that accretions between La Grange and Modesto tend to increase with higher flow. However, the EC at Modesto tended to be higher at lower flows, when accretions were low (Figure F.2-1h). This trend indicates that Tuolumne River EC is probably affected by a relatively small volume of salty inflow (e.g., agricultural drainage). Despite the higher EC at lower flow, EC at the downstream end of the Tuolumne River at Modesto (50-300 µS/cm) was still well below the EC in the LSJR upstream of the Tuolumne River (usually 1,000 to 1,500 µS/cm as described above), and, therefore, helped to reduce EC in the LSJR.

Figure F.2-1i shows the historical monthly SJR flows and EC values at Maze, located downstream of the Tuolumne River and upstream of the Stanislaus River. The SJR flows at Maze generally ranged from 250–2,500 cfs, with lower flows in the dry years and flows of more than 5,000 cfs in wet years. The EC values at Maze were measured by DWR prior to 1992 and since 2007, but were estimated from the Vernalis flow and EC subtracting the Stanislaus flow and EC for the intermediate years. During wet years, the Maze EC ranged from less than 250 µS/cm to about 1,000 µS/cm. The Maze EC ranged from 1,000–2,000 µS/cm in the 1988–1994 dry period, but the EC has been less than 1,250 µS/cm since 2000. The Tuolumne River flows measured at Modesto are shown to indicate the dilution effect from the low EC water from the Tuolumne River. The Tuolumne River flow was generally 100–500 cfs, with flows of more than 1,000 cfs only in the wet years (flood control releases). This EC data suggests that the SJR at Maze has a moderate salinity with EC values generally less than 1,000 µS/cm, except when flow is less than 1,000 cfs.

Figure F.2-1j shows the Stanislaus River EC near the downstream end at Ripon as well as flow at Ripon and upstream at Goodwin. The data indicate that there is generally a 0 to 200 cfs increase in flow between Goodwin and Ripon, with only a slight trend for higher accretions at higher flows (Figure F.2-1k). EC at Ripon tends to be low (75-150 µS/cm), which indicates a relatively small increase in salt load along the length of the lower Stanislaus River. Even at the lowest flows (200-400 cfs at Ripon), EC generally remained below 150 µS/cm. EC at the downstream end of the Stanislaus River at Ripon was well below the EC in the LSJR upstream of the Stanislaus River (generally between 250 and 1,250 µS/cm since water year 1995 as described above for Maze), and, therefore, helped to reduce EC in the LSJR.

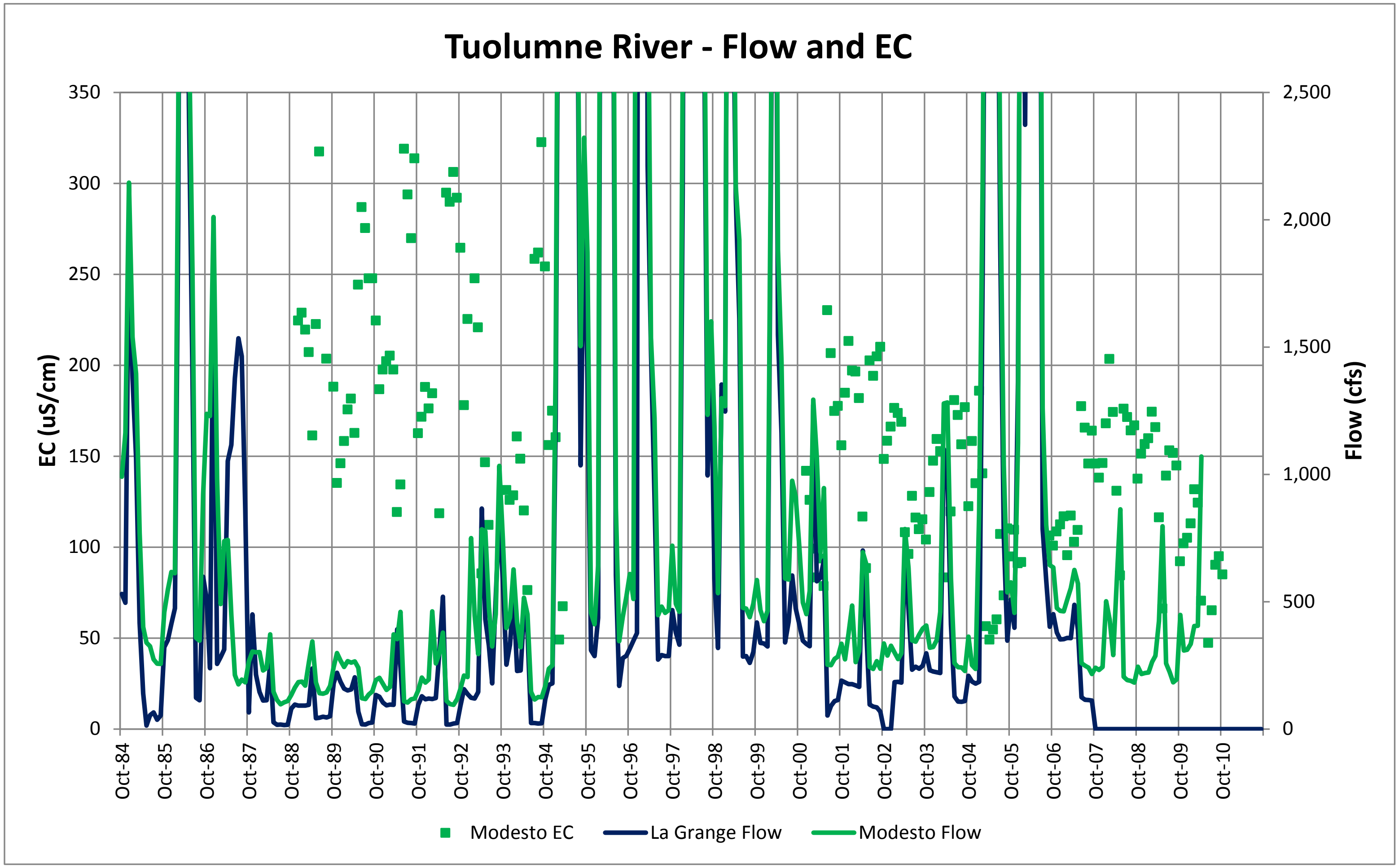


Figure F.2-1g. Time Series of Historical Monthly Flow and EC in the Tuolumne River for WY 1985–2011

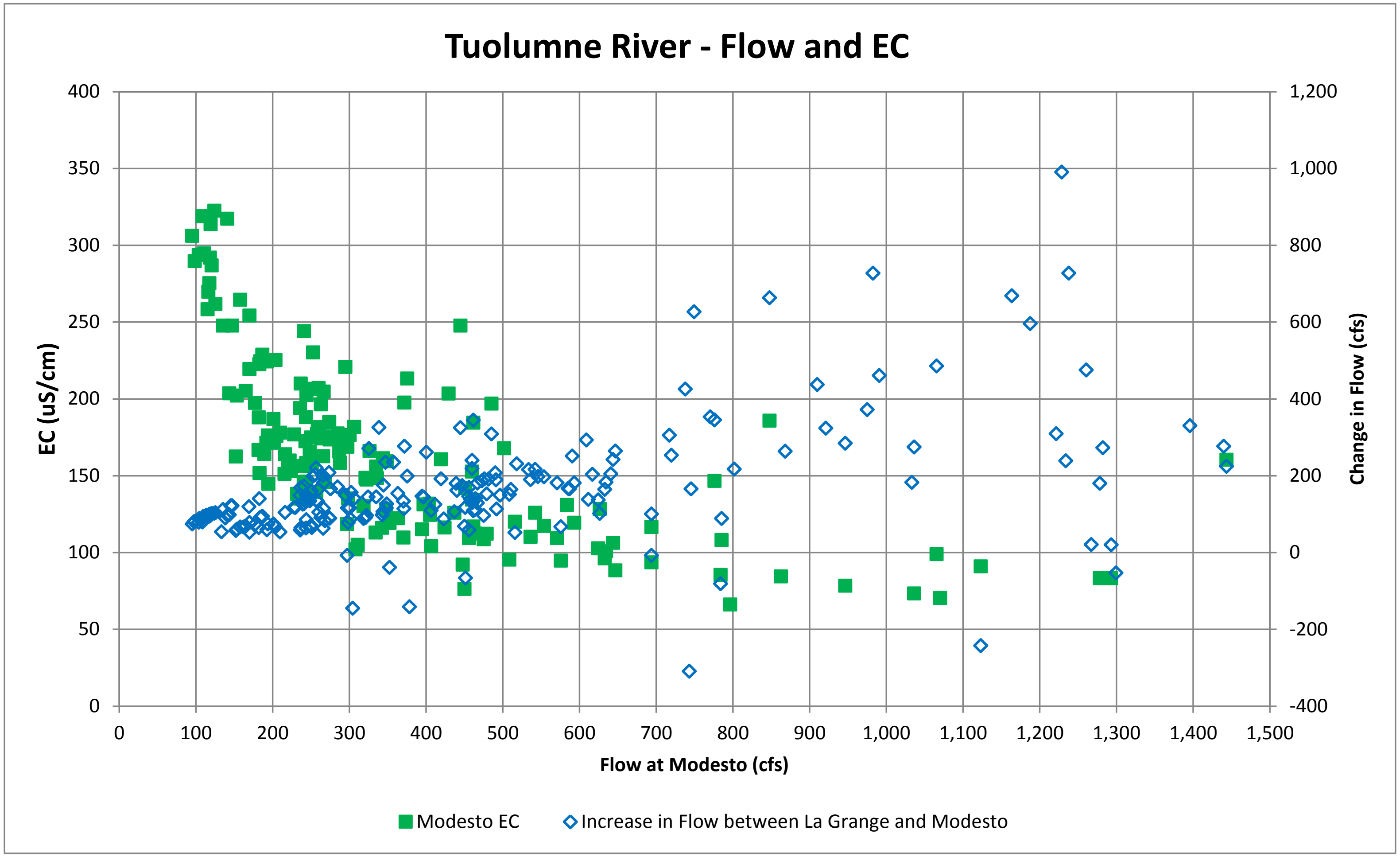


Figure F.2-1h. Relationship between Monthly Tuolumne River Flow, Accretions, and EC for WY 1985–2011

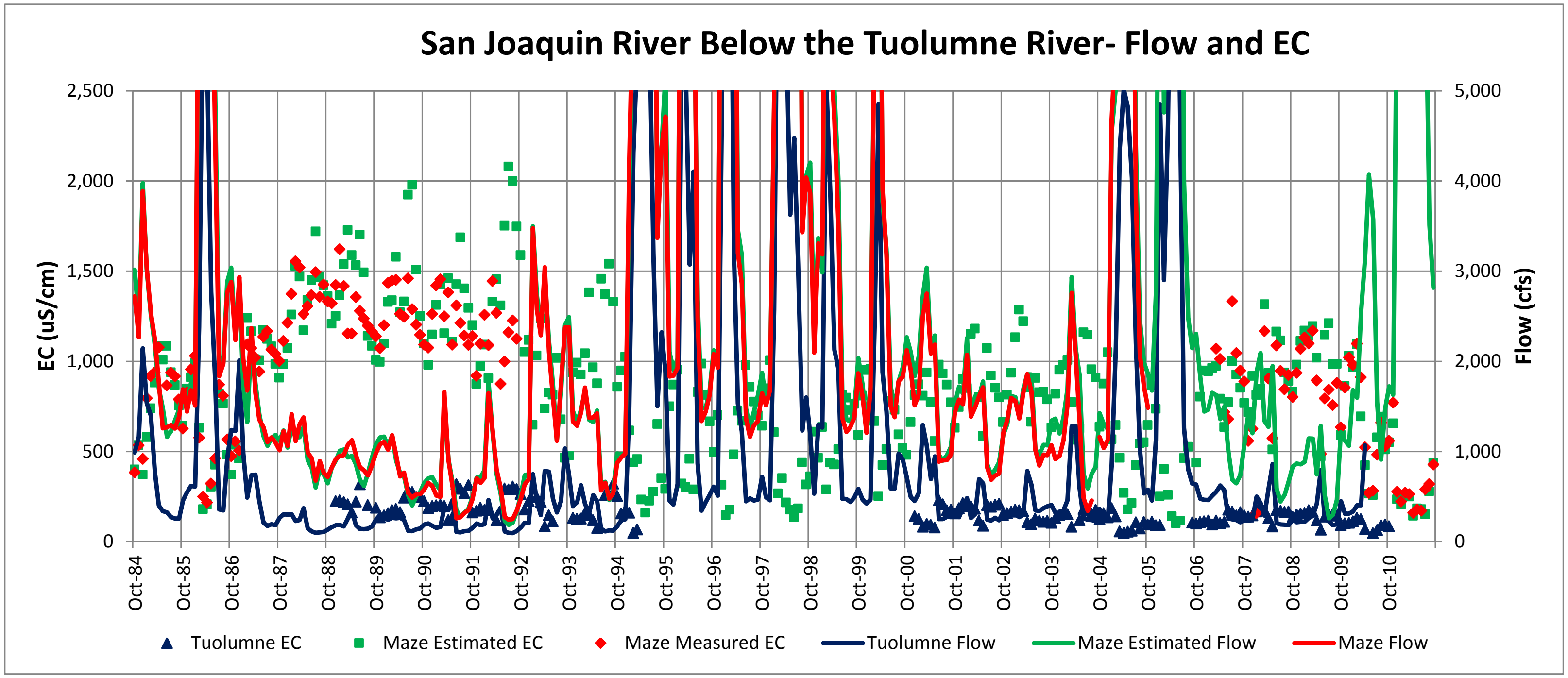


Figure F.2-1i. Historical Monthly Flow and EC in the San Joaquin River Downstream of the Tuolumne River for WY 1985–2011

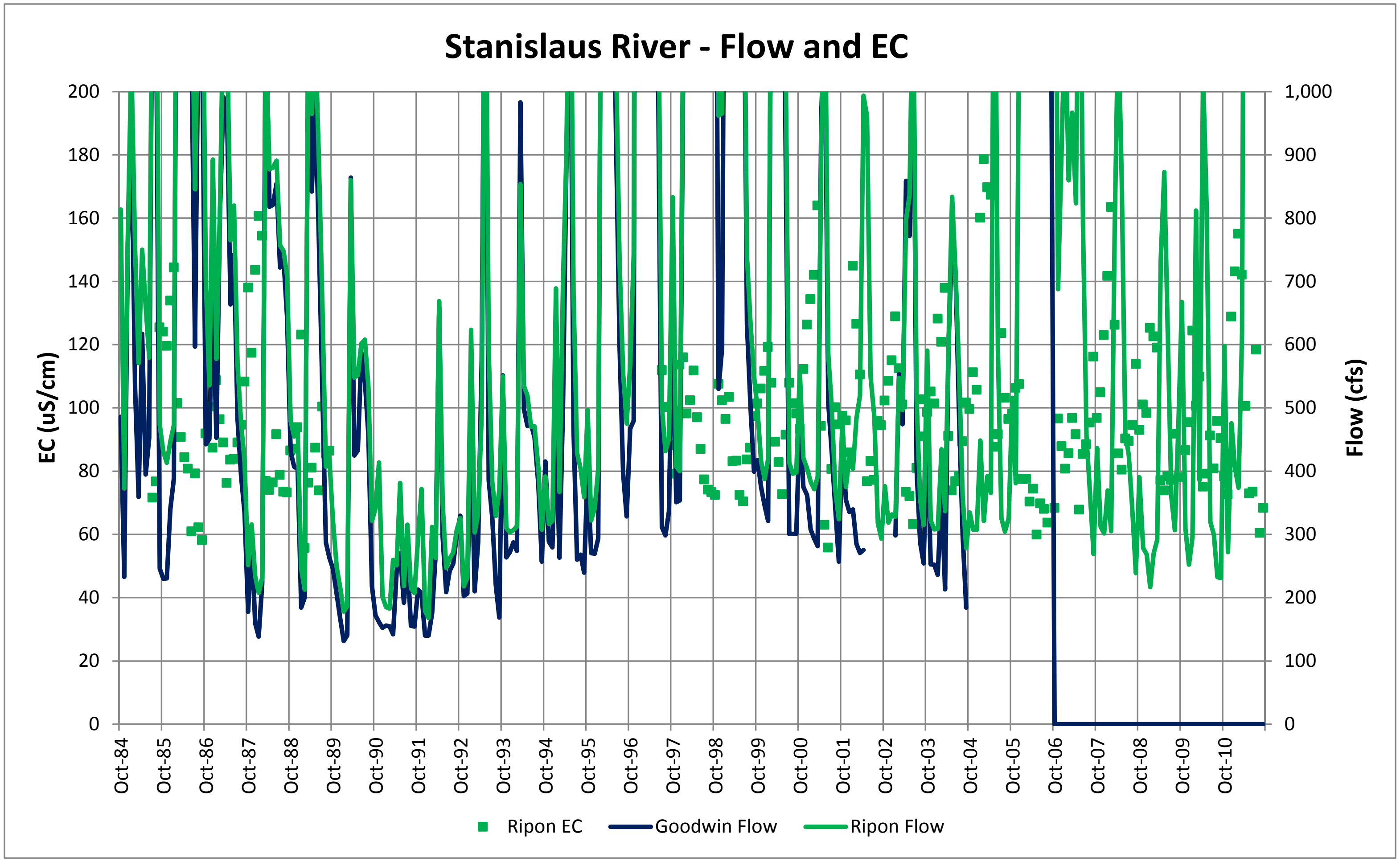


Figure F.2-1j. Time Series of Historical Monthly Flow and EC in the Stanislaus River for WY 1985–2011

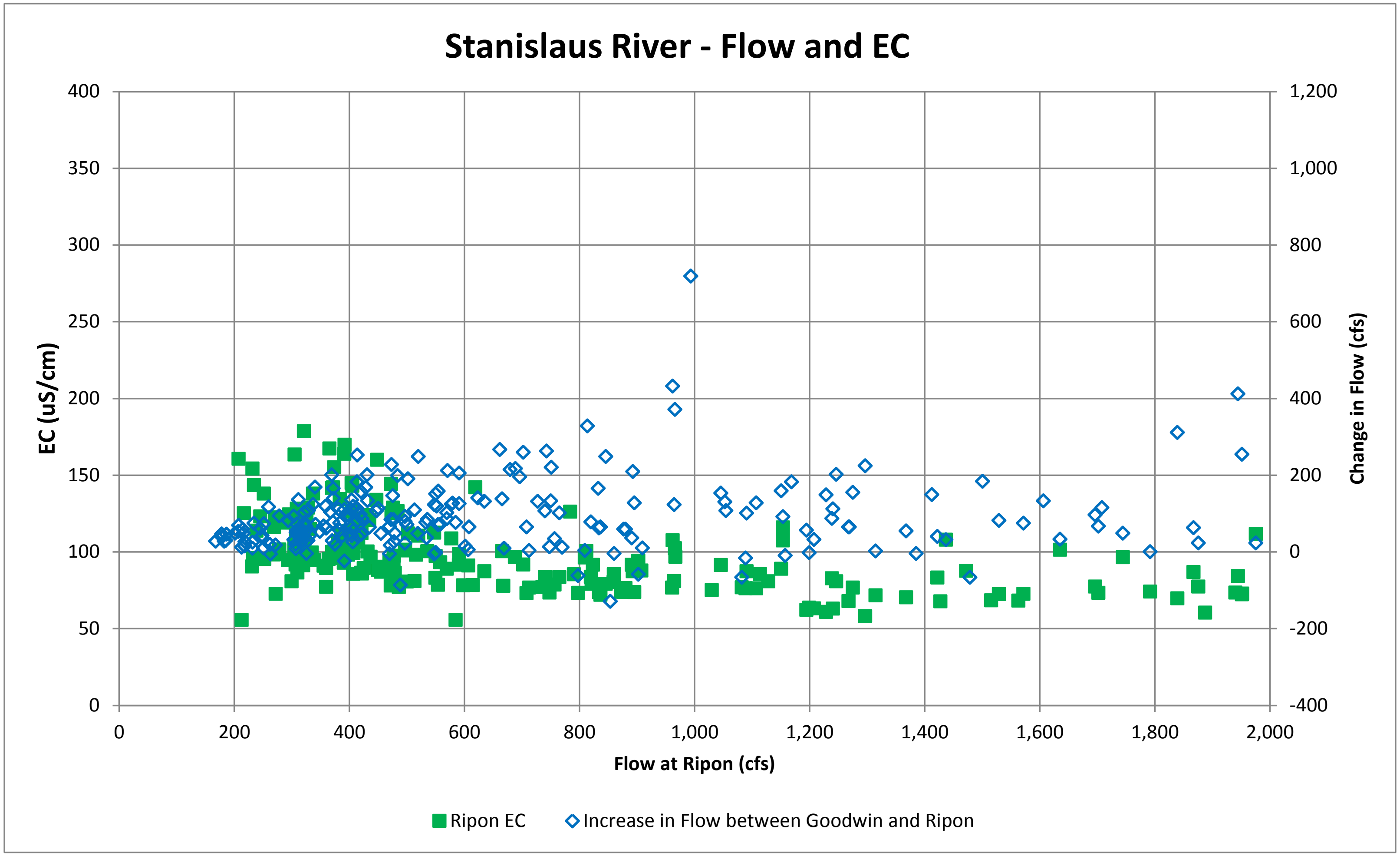


Figure F.2-1k. Relationship between Monthly Stanislaus River Flow, Accretions, and EC for WY 1985–2011

Figure F.2-1l shows the historical monthly flows and EC values at Vernalis, located just downstream of the Stanislaus River inflow. The SJR flows at Vernalis generally ranged from 1,000–5,000 cfs, with lower flows of 500 cfs in dry years and flows of more than 5,000 cfs in wet years. The EC values at Vernalis ranged from less than 250 µS/cm in high flow months to about 1,250 µS/cm. The Vernalis EC ranged from 750–1,250 µS/cm in the 1988–1994 dry period, but the EC has been less than 1,000 µS/cm since 2000. There are three separate EC measurements at Vernalis (DWR, United States Bureau of Reclamation [USBR], and USGS). There are often differences of 25 µS/cm between these monthly data. The existing Vernalis EC objectives of 700 µS/cm from April–August and 1,000 µS/cm from September–March have been applicable since 1996. The Stanislaus River flows measured at Ripon are shown to indicate dilution effects from the lower EC water. The Stanislaus River flows were generally 250 cfs–1,000 cfs, with flows of more than 1,000 cfs only in wet years (flood control releases). As described above, the Stanislaus River EC values were generally 75–150 µS/cm. This EC data suggests that the SJR at Vernalis has a moderate salinity with EC values generally between 250 µS/cm and 750 µS/cm, except when flow is less than 1,000 cfs.

Figure F.2-1m shows the historical monthly flows and calculated salt loads at Vernalis. The monthly salt load at Vernalis ranged from about 25,000 tons (when flow was about 1,000 cfs) to more than 150,000 tons (when flow was more than 5,000 cfs). Because the SJR at Vernalis EC was generally 250–750 µS/cm (average of 500 µS/cm) since 1996, the salt load was generally proportional to the flow. At low flows there can be a wide variation in the EC as the salt load in the SJR remains relatively constant from Salt and Mud Sloughs and from the groundwater inflow from agriculture along the SJR between the Merced River and the Stanislaus River. High releases from the Stanislaus River produce a strong dilution effect on salinity at Vernalis, while high runoff from watersheds downstream of the tributary reservoirs can add a larger salt load from surface soil leaching.

Figure F.2-1n provides a summary graph showing the general relationship between historical SJR at Vernalis flow and EC measurements from 1985–2011. For flows of less than 1,000 cfs, there have been a wide range of EC values, from 500–1,250 µS/cm. At a flow of 2,500 cfs, the range of EC values has also been large, from 400–800 µS/cm. At a flow of 5,000 cfs, the range of historical EC was 250–500 µS/cm. At a flow of 10,000 cfs, the SJR at Vernalis EC was generally about 250 µS/cm. This general dilution effect can be characterized as a partial flow dilution with an approximate relationship of:

$$\textit{Vernalis EC } (\mu S/cm) = 15{,}000 \times \textit{flow } (cfs)^{-0.4}$$

This general dilution pattern indicates the EC would be about 1,000 µS/cm at a flow of 1,000 cfs and would decrease to about 500 µS/cm at a flow of 5,000 cfs. The salt load always increases with flow, but at a slower rate as flow increases. The salt load would be about 50,000 tons/month at a flow of 1,000 cfs and would increase to 100,000 tons/month at a flow of 3,000 cfs. The salt load would be about 150,000 tons/month at a flow of 6,000 cfs and would be about 200,000 tons/month at a flow of 10,000 cfs. These approximate EC and salt load lines have been selected to provide a maximum likely EC and salt load at various river flows; most of the historical EC values have been less than the approximate line.

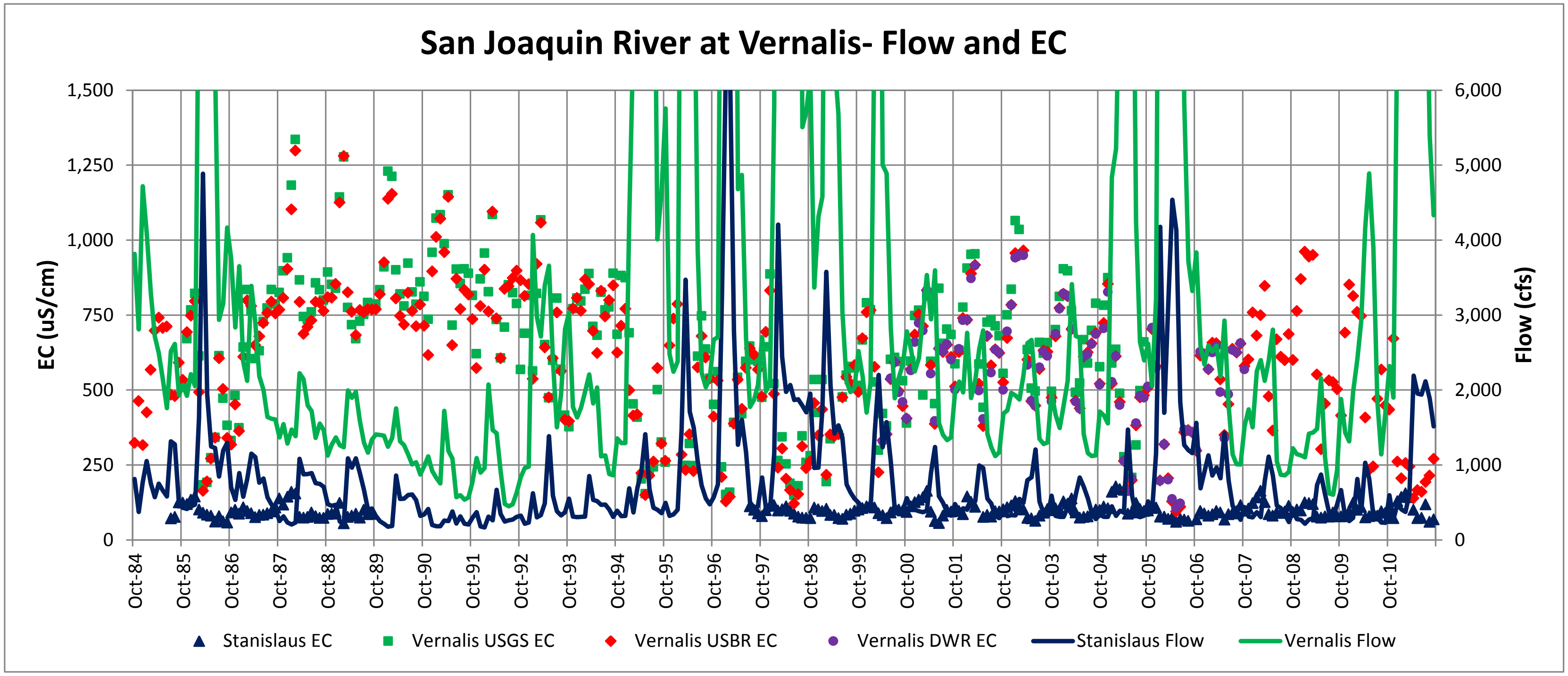


Figure F.2-1l. Historical Monthly Flow and EC in the San Joaquin River at Vernalis for WY 1985–2011

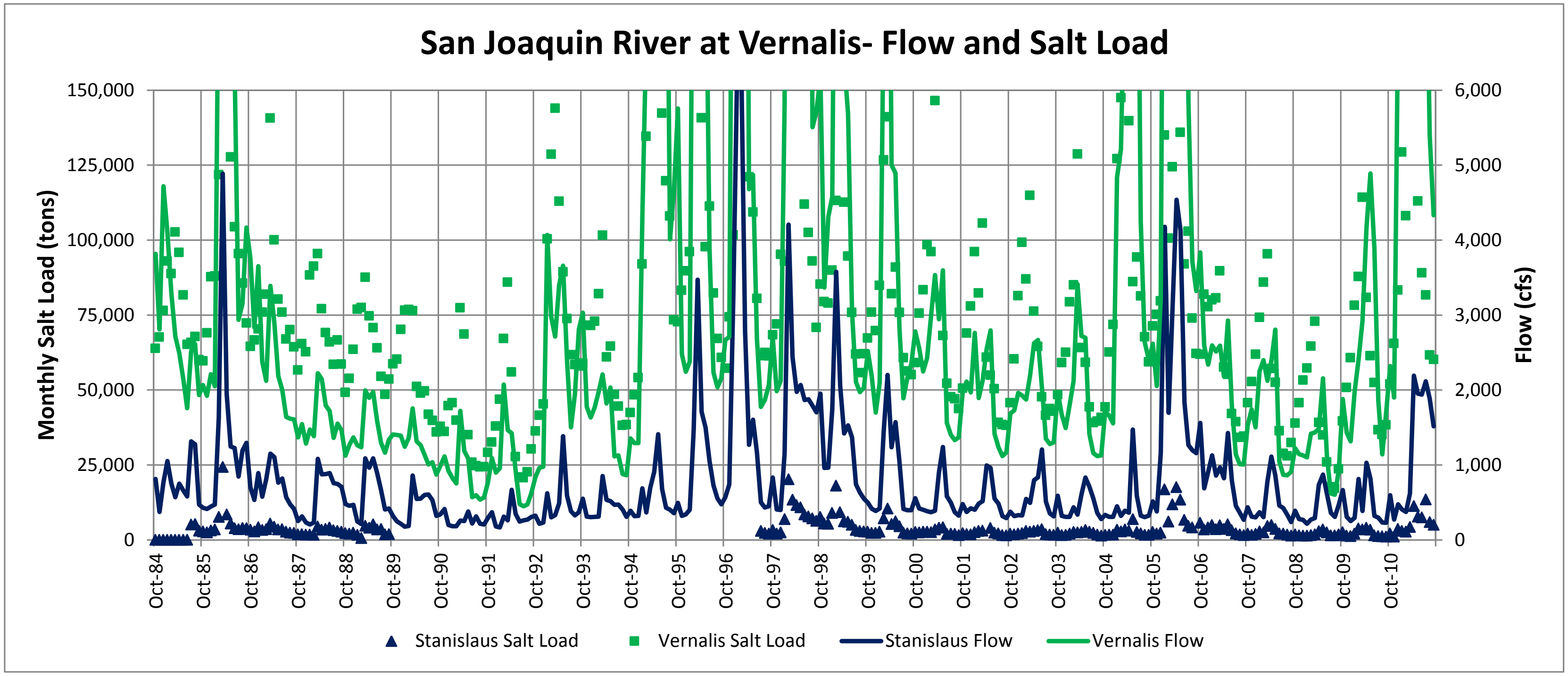


Figure F.2-1m. Historical Monthly Flow and Salt Load (tons) in the San Joaquin River at Vernalis for WY 1985–2011

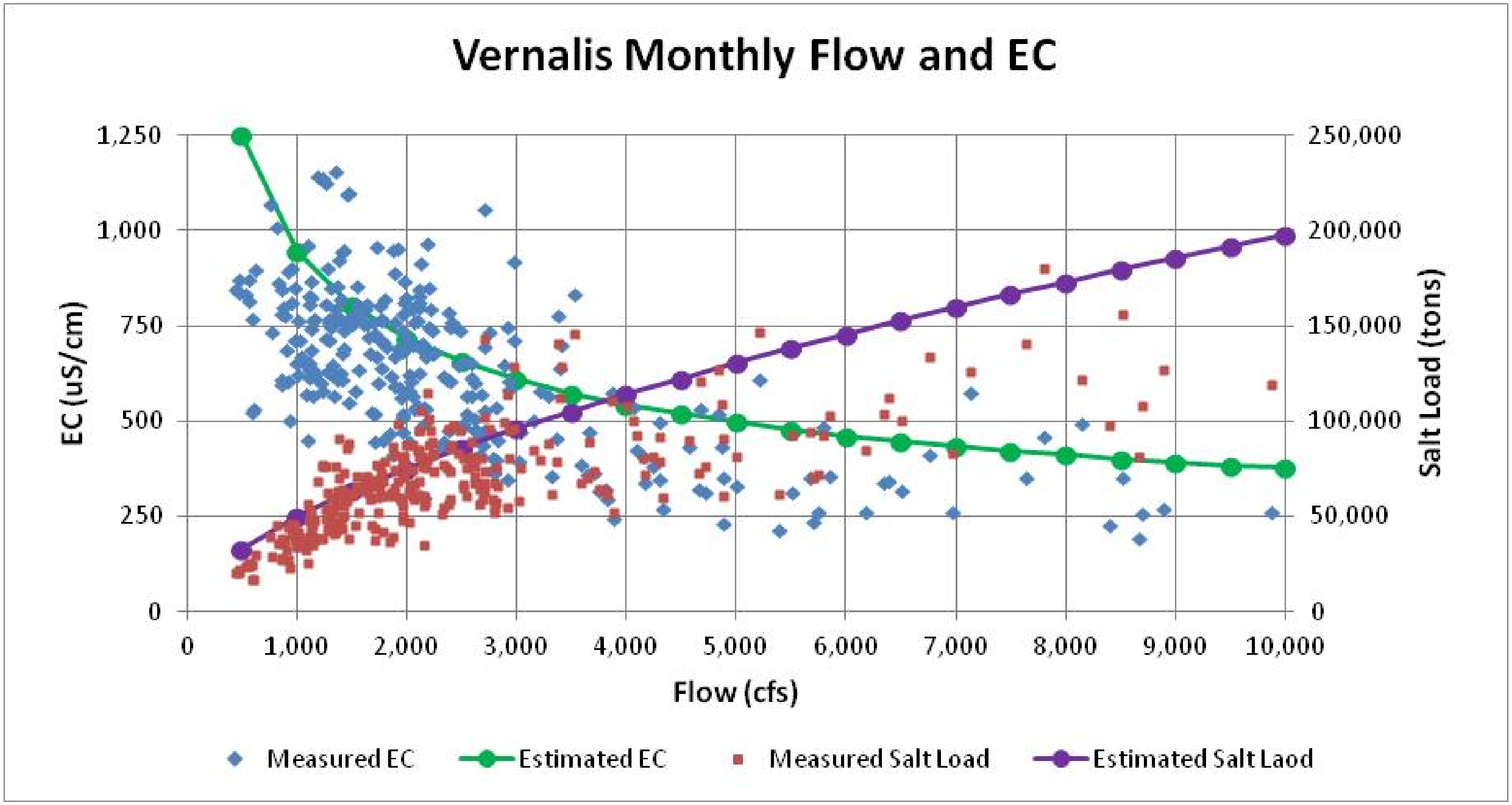


Figure F.2-1n. Relationship between SJR at Vernalis Monthly Measured Flow and EC and Calculated Salt Load for WY 1985–2011

F.2.3 Daily Flow and Salinity (EC) in the SJR for 2000–2003

The flow and salinity patterns along the SJR will be introduced and described by reviewing the measured flows and salinity from four recent years: 2000–2003. Daily flows and EC values at several gages along the SJR and for some tributary inflows will be shown to illustrate seasonal and storm event patterns of SJR flow and salinity.

F.2.3.1 Measured SJR Flow and Salinity in 2000

Figure F.2-2a shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR near Stevinson (upstream of Salt Slough) for 2000. The SJR at Stevinson flows are the combination of Bear River (watershed includes the City of Merced), irrigation return flows, and (in wet years) flood flow releases from Friant Dam. The highest flows are often observed in January–March. The flows in 2000 were increased by local storms in late January, February, March, and April; Friant Dam flood control releases were made in March. The spring flows in April–June were about 100 cfs, and the summer flows in July–September were about 50 cfs. The fall flows in October had two spikes (unknown source) and the flows in November and December were less than 25 cfs. The EC measurements in the SJR at Stevinson began in July 2000. The summer and fall EC was about 1,000–1,500 µS/cm when flow was 25–50 cfs and was reduced to less than 500 µS/cm when flows increased to 100 cfs or more. The salt load (tons/day) can be calculated for days with flow and EC measurements. The salt load was about 100 tons/day in August with a flow of 50 cfs and EC of about 1,000 µS/cm. The salt load was about 50 tons/day in the fall months with lower flows of about 25 cfs.

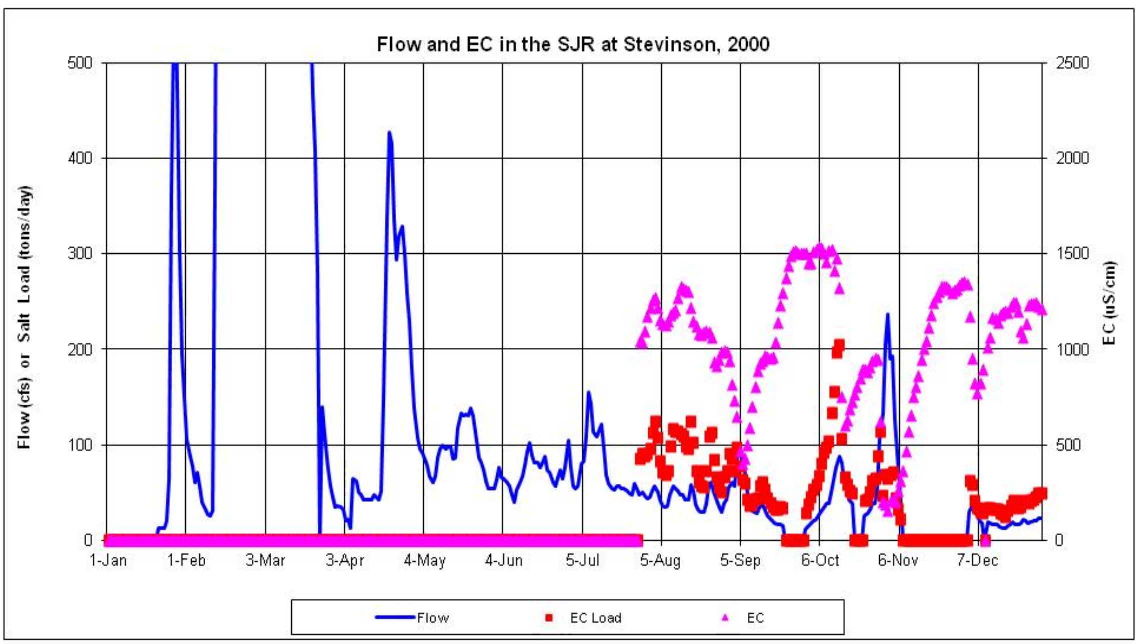


Figure F.2-2a. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Stevinson during 2000

Figure F.2-2b shows the daily flow and EC, with the calculated salt load (tons/day) for Salt Slough for 2000. The Salt Slough flows are the combination of irrigation return flows, discharges from the Grasslands wetlands, and local rainfall runoff. The tile drainage from the Grasslands Drainage Area (with high selenium) has been isolated from Salt Slough with the Grasslands Bypass Project since 1998, using the San Luis Drain, with discharges to Mud Slough. The highest flows are often observed January–April. The maximum flows were more than 500 cfs following local storms in late January, February, March, and April of 2000. The spring flows in April–June were about 200 cfs, and the summer flows in July–September decreased from about 200 cfs to about 150 cfs. The fall flows in October–December were about 150–200 cfs. The Salt Slough EC measurements in 2000 were about 2,000 µS/cm in January when flow was about 100 cfs, were gradually reduced to about 1,500 µS/cm by the end of March, were about 1,000 µS/cm during summer months, and were slightly increased to about 1,500 µS/cm in fall months. The salt load in Salt Slough in 2000 was 500–1,000 tons/day in winter months and was 250–500 tons/day in the spring, summer, and fall months. The flow, EC measurements, and resulting salt load pattern were comparatively uniform through the year in Salt Slough.

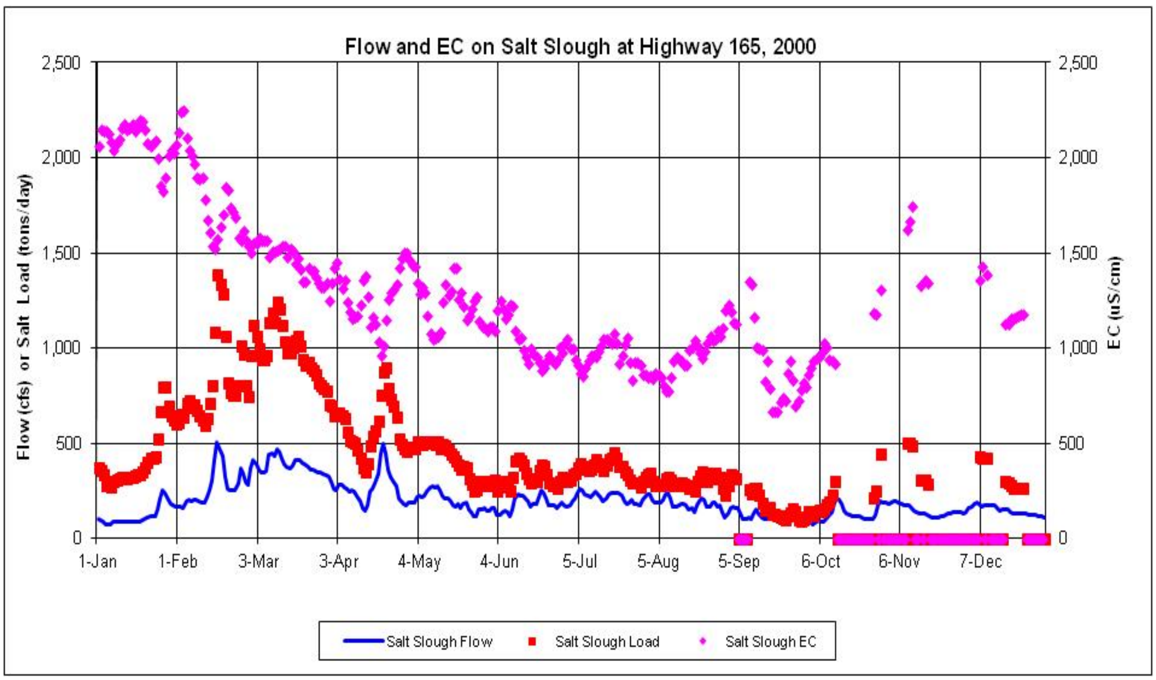


Figure F.2-2b. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in Salt Slough at Highway 165 during 2000

Figure F.2-2c shows the daily flow and EC, with the calculated salt load (tons/day) for Mud Slough for 2000. The Mud Slough flows are the combination of irrigation return flows, discharges from the San Luis Drain, discharges from Grasslands wetlands, and local runoff. The highest flows are often in January–April. The maximum flows in 2000 were about 300 cfs following local storms in late January and February; however, this is also when many wetlands are drained following duck season. The spring flows in April–June were about 50–100 cfs, the summer flows in July–September were about 50 cfs, and the fall flows in October–December were about 150–200 cfs. The San Luis Drain discharge flow is shown for comparison; the San Luis drain is the major source of flow in spring and summer months. Mud Slough EC measurements in 2000 were about 2,000–4,000 μS/cm in winter and fall when flows were about 100–250 cfs and were about 3,000 μS/cm in spring and summer months when the San Luis Drain contributed most of the 50 cfs flow. The EC in the San Luis Drain was generally 4,000–5000 μS/cm. The salt load in Mud Slough in 2000 was about 500 tons/day through most of 2000. The salt loads were about 1,000 tons/day in February and March (higher flows) and were about 250 tons/day in August and September. The flow, EC measurements, and resulting salt load pattern were comparatively uniform through the year in Salt Slough. Salt Slough and Mud Slough represent the major sources of salt load upstream of the Merced River; each contributes about 250–1,000 tons/day to the SJR.

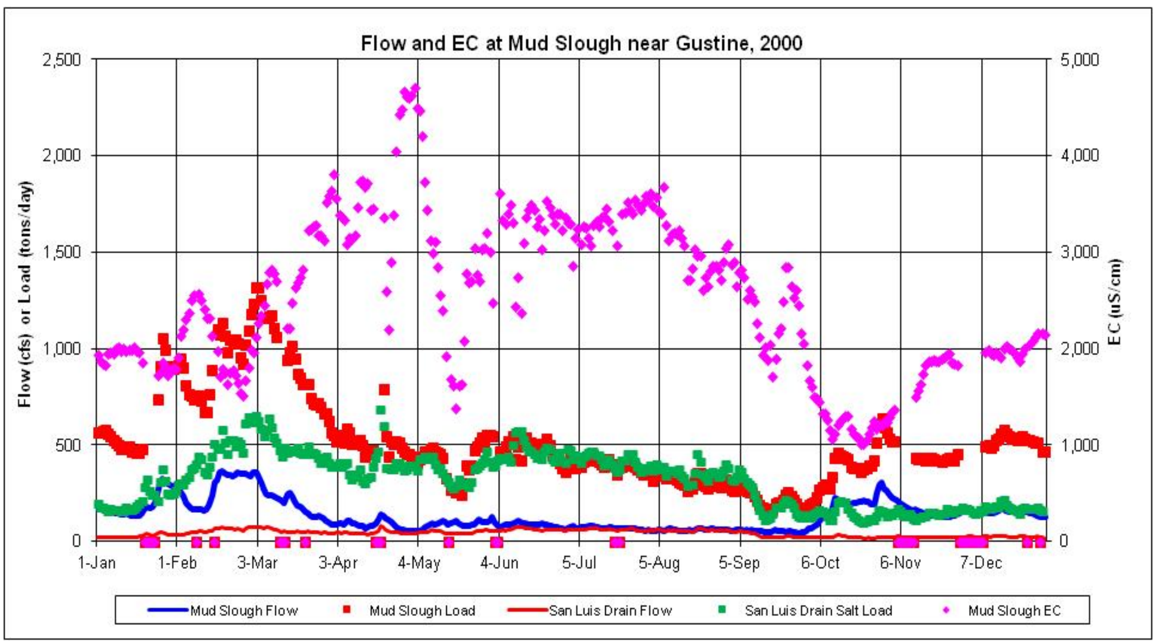


Figure F.2-2c. Daily Measured Flow (cfs) and EC (μS/cm) and Calculated Salt Load (tons/day) in Mud Slough near Gustine and in the San Luis Drain Discharge to Mud Slough during 2000

Figure F.2-2d shows the daily flow and EC, with the calculated salt load (tons/day) for the Merced River for 2000. The Merced River flows are the combination of releases from Lake McClure, irrigation return flows, and local rainfall runoff. The highest flows are often observed in January–April. The maximum flows in 2000 were greater than 2,500 cfs in February and March. Merced River flows were about 250 in January and June, decreasing to about 150 cfs in the summer months of July–September, and increasing to 500–1,000 cfs in October–December for hydropower generation and flood control storage releases. The Merced River EC measurements began in August 2000 and were 200–300 µS/cm in August and September. The EC was reduced to 50–150 µS/cm by the higher flows of 500–1500 cfs in October–December. The Merced River salt load in 2000 was about 50–100 tons/day from August–December. Because the Merced River EC is low (50–300 µS/cm), the salt load is much less than the salt load from the SJR upstream of the Merced River.

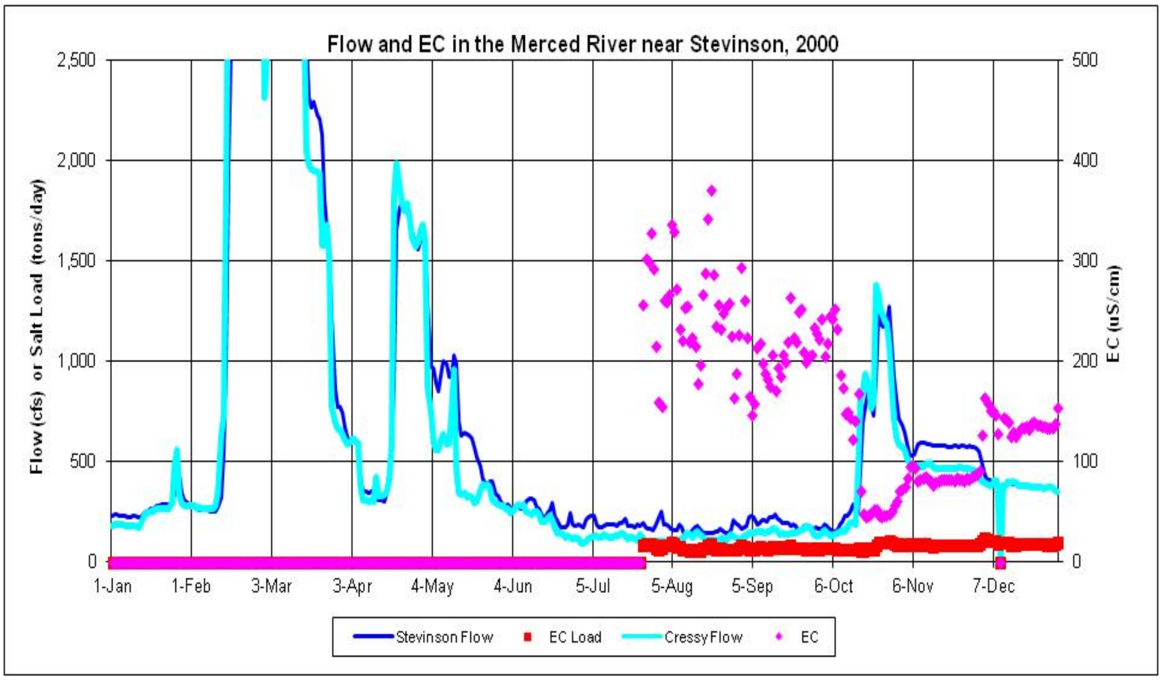


Figure F.2-2d. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the Merced River near Stevinson during 2000

Figure F.2-2e shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Crows Landing (downstream of Merced River) for 2000. The Merced River flows are shown for comparison. The SJR flows at Crows Landing were greater than 5,000 cfs in February–March but were generally 750–1,000 cfs in most months without a flood event or reservoir release (October). Because the Merced River contributes about 25 to 50 percent of the SJR flow at Crows Landing, the maximum EC measurements of about 1,000–1,500 µS/cm were considerably less than the EC measured in the SJR at Stevinson or in Mud and Salt Sloughs (i.e., dilution). The Crows Landing EC measurements in 2000 were reduced to 500 µS/cm during higher flows in February–March and October. The SJR at Crows Landing salt loads in 2000 were about 1,000–2,000 tons/day in most months, with higher salt loads of 3,000–5,000 tons/day during high flows in February and March. Because the Merced River salt loads were generally 50–100 tons/day, the great majority of the salt load in the SJR at Crows Landing originated from upstream of the Merced River.

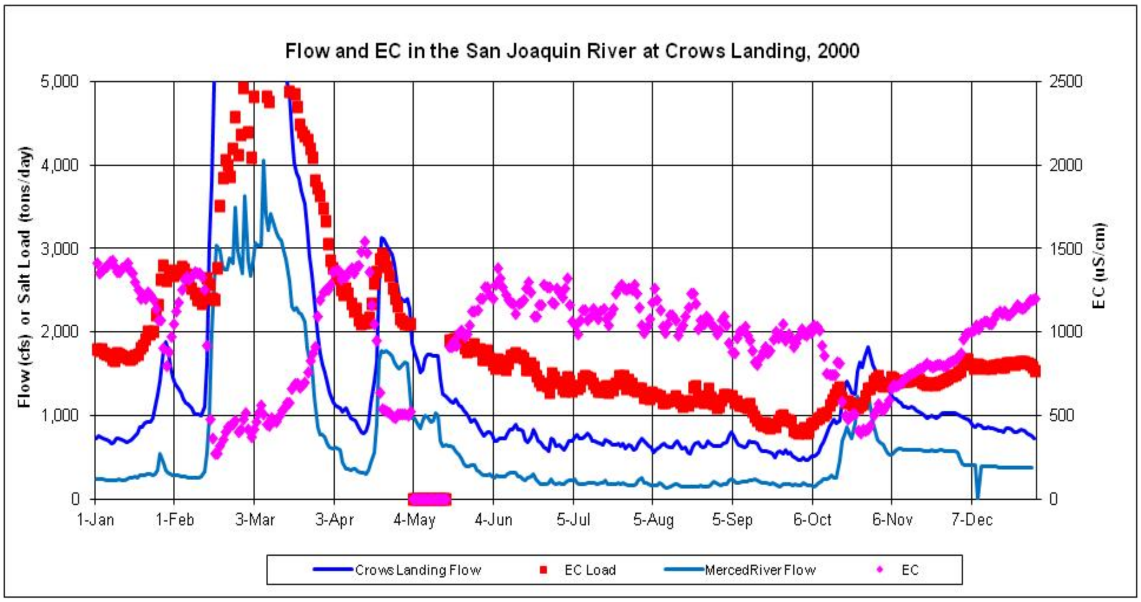


Figure F.2-2e. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Crows Landing (downstream of the Merced River) during 2000

Figure F.2-2f shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Maze (downstream of Tuolumne River, upstream of Stanislaus River) for 2000. The Tuolumne River flows are shown for comparison. The SJR flows at Maze were greater than 5,000 cfs for parts of February and March, and were greater than 2,500 cfs through May of 2000. Flows were 1,500–2,500 cfs for summer and fall. The Tuolumne River flow was about 500 cfs for most of the year, with major flood releases in winter and some additional releases in August. EC measurements at Maze were not made in 2000 but have been estimated by adjusting the SJR at Vernalis flow and EC with the Stanislaus at Ripon flow and EC. The Maze EC estimates in 2000 were about 1,000 µS/cm in January but were reduced to 250 µS/cm during higher flows in February–March. The estimated Maze EC values were 500–1,000 µS/cm for summer and fall. Because the Tuolumne River contributes about 25 to 50 percent of the SJR flow at Maze, the maximum EC measurements of about 1,000 µS/cm were somewhat less than the EC measured in the SJR at Crows Landing. There were some agricultural diversions between Crows Landing and Maze, and additional inflows to the SJR from agricultural drainage and shallow groundwater seepage to the river. The SJR at Maze salt loads in 2000 were about 2,000–3,000 tons/day in most months, with higher salt loads of 3,000–5,000 tons/day during high flows of February and March. Because the Tuolumne River salt loads were generally 100 tons/day, the great majority of the salt load in the SJR at Maze originated from upstream of the Merced River or from agricultural drainage and shallow groundwater seepage to the SJR.

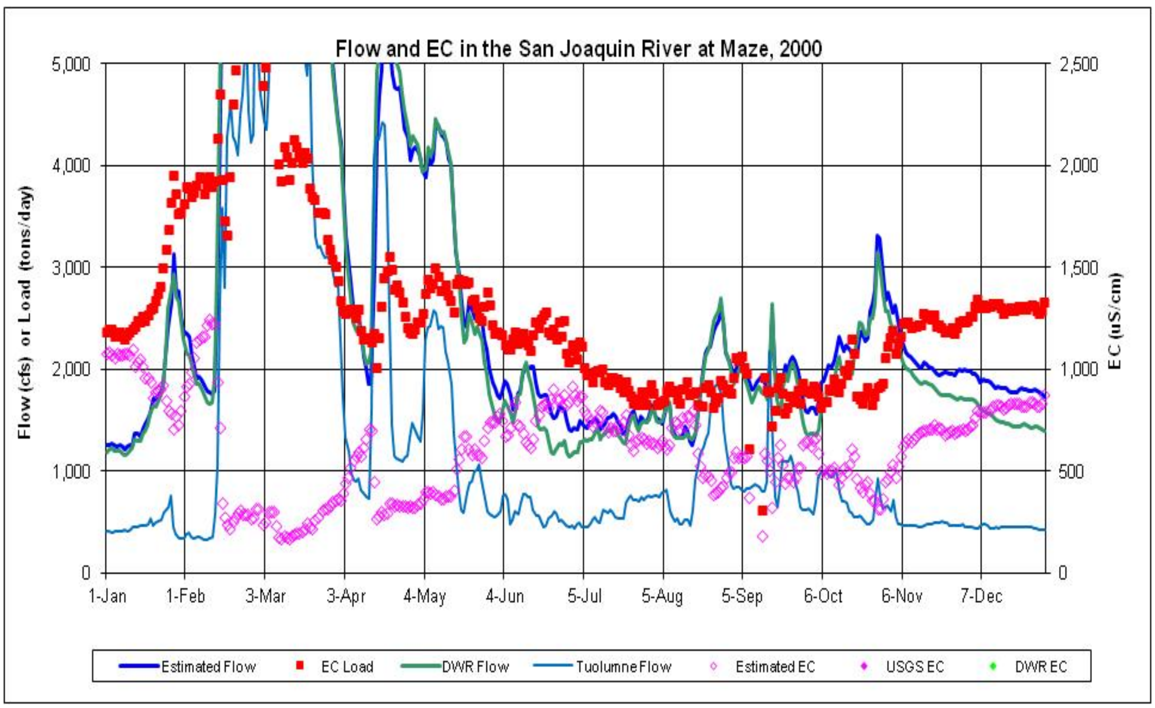


Figure F.2-2f. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Maze (downstream of the Tuolumne River) during 2000

Figure F.2-2g shows the daily flow and EC, with the calculated salt load (tons/day) for the Stanislaus River for 2000. The Stanislaus River flows are the combination of releases from New Melones Reservoir, irrigation return flows, and local rainfall runoff. The flows at Goodwin and Ripon are shown for comparison. The highest flows were more than 2,500 cfs in February–March (flood control release) and 1,500 cfs during the extended VAMP period from mid-April to mid-June. A mid-October pulse flow release of 1,000 cfs was made for adult fish attraction. The Stanislaus flows were about 400 cfs in other months of 2000. The Stanislaus River EC measurements at Ripon ranged from 75 µS/cm during high flow periods to about 150 µS/cm in January. The Ripon EC was about 100 µS/cm during summer. The Stanislaus River salt load in 2000 was a maximum of 500 tons/day during peak flows in February and March, about 200 tons/day in April–June (higher fish flows), and about 75–100 tons/day from July–December. The Stanislaus River flows are dominated by releases from Goodwin Dam to provide fish flows and flood control releases.

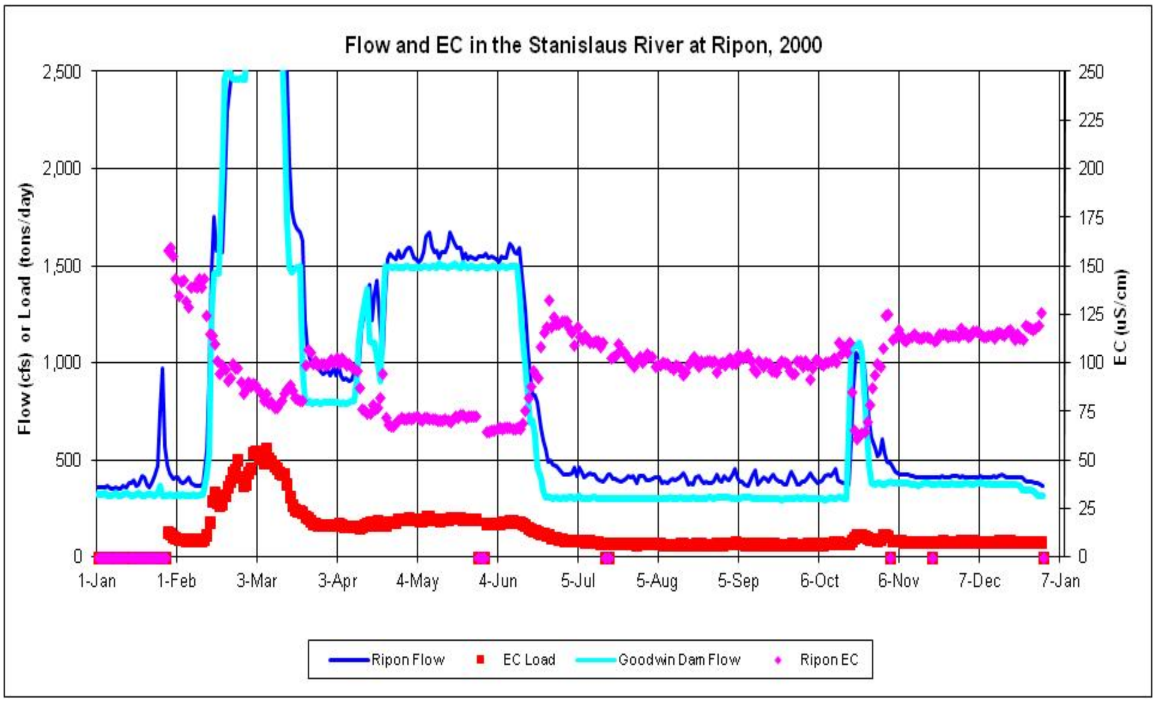


Figure F.2-2g. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the Stanislaus River at Ripon during 2000

Figure F.2-2h shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Vernalis (downstream of Stanislaus River) for 2000. The Stanislaus River flows are shown for comparison. The SJR flows at Vernalis were greater than 5,000 cfs for parts of February –May and were greater than 2,000 cfs through the remainder of 2000. The minimum flows were observed in July and August, and flows of about 2,500 cfs were measured from mid-August through November. These Vernalis flows were much higher than the minimum 1,000 cfs measured in summer months of other years. The Vernalis EC measurements in 2000 were about 800 µS/cm in January but were reduced to 250 µS/cm during higher flows in February–March. The Vernalis EC values ranged from 250–750 µS/cm during the remainder of the year, generally following a flow-dilution relationship. For example, the Vernalis EC increased in November and December from about 500 µS/cm to 750 µS/cm as flows decreased from 2,500 cfs to 2,000 cfs. Some indication of the accuracy of the EC measurements is shown by the three separate Vernalis EC measurements; the USGS, USBR, and DWR each make independent measurements of the Vernalis EC. These independent EC measurements are generally within 25–50 µS/cm of each other (i.e., clock shop dilemma). The SJR at Vernalis salt loads in 2000 ranged from 2,000 tons/day from July–October to more than 5,000 tons/day during peak flow in February and March. Increased flows from rainfall runoff or reservoir releases will not increase the salt load by nearly as much as seasonal variations in tile drainage and shallow groundwater seepage flows. The monthly average Vernalis EC values were much less than EC objectives in 2000. Some daily EC values approached the objectives, but not the 30-day moving average (or monthly average) values. Because the Vernalis EC did not approach EC objectives in 2000, there were no additional New Melones releases for salinity control; all New Melones releases in 2000 were for fish flows or flood control.

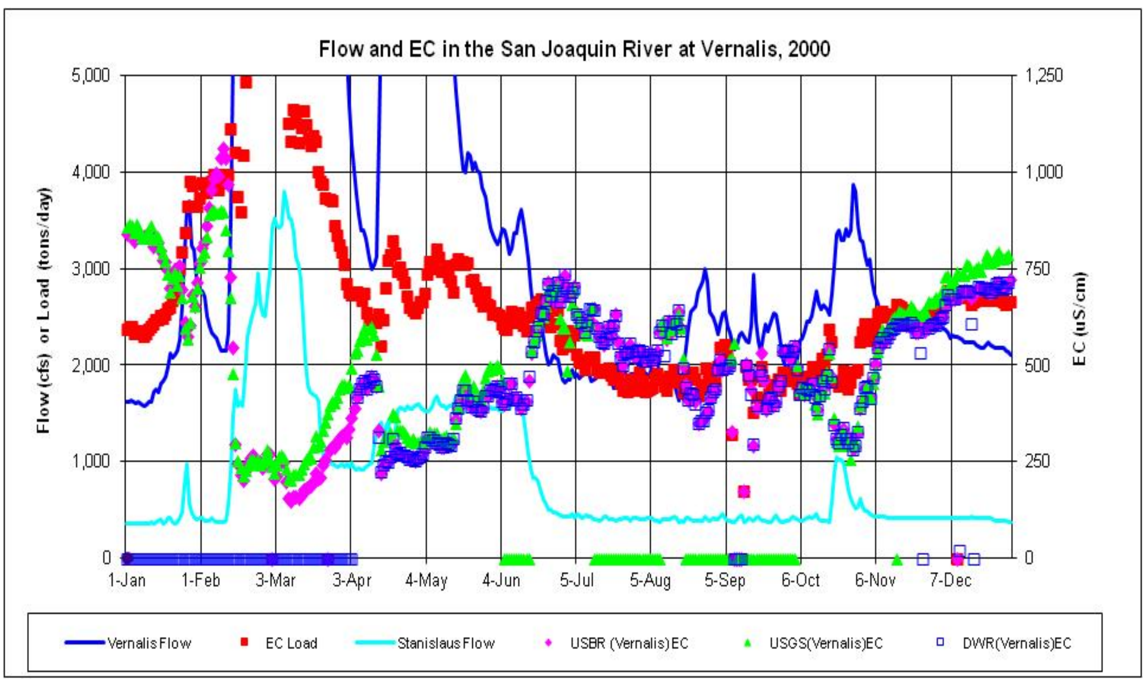


Figure F.2-2h. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the San Joaquin River at Vernalis during 2000

F.2.3.2 Measured SJR Flow and Salinity in 2001

Figure F.2-3a shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR near Stevinson for 2001. The flows in 2001 were increased by a series of small storms; flows remained less than 500 cfs and were less than 25 cfs from May through November. The EC measurements in the SJR at Stevinson were about 1,000–1,500 µS/cm when the flow was 25–50 cfs and were reduced to less than 500 µS/cm when flows increased to 100 cfs or more. The salt load was 100–200 tons/day in winter with flows of 50–100 cfs and was less than 50 tons/day for most of the year with flows of about 25 cfs.

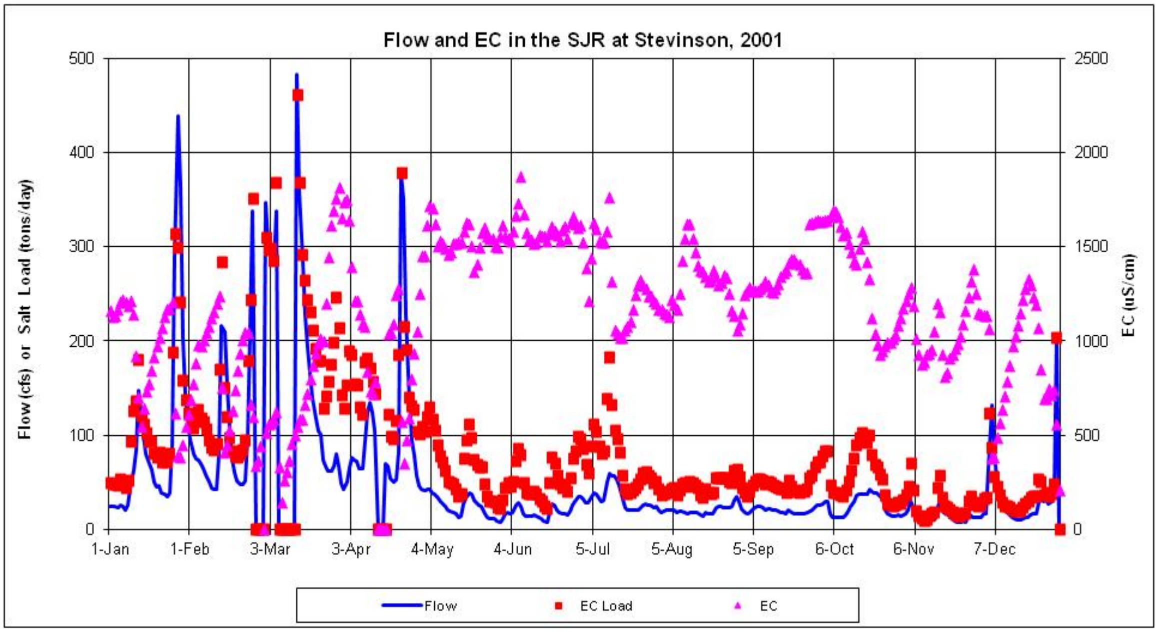


Figure F.2-3a. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Stevinson during 2001

Figure F.2-3b shows the daily flow and EC, with the calculated salt load (tons/day) for Salt Slough for 2001. The maximum flows were about 500 cfs in early March and were less than 250 cfs from April–December. The Salt Slough EC measurements in 2001 were about 1,500 µS/cm in January–April, gradually reduced to about 1,000 µS/cm in July and August, increased to 1,500 µS/cm when flows were reduced in September–November, and were about 2,500 µS/cm in December when flows were again reduced. The salt load in Salt Slough in 2001 was 500–1,000 tons/day in winter and was 250–500 tons/day in spring, summer, and fall. The flow, EC measurements, and resulting salt load pattern were comparatively uniform through the year in Salt Slough. Reduced flows appeared to be associated with increased EC values.

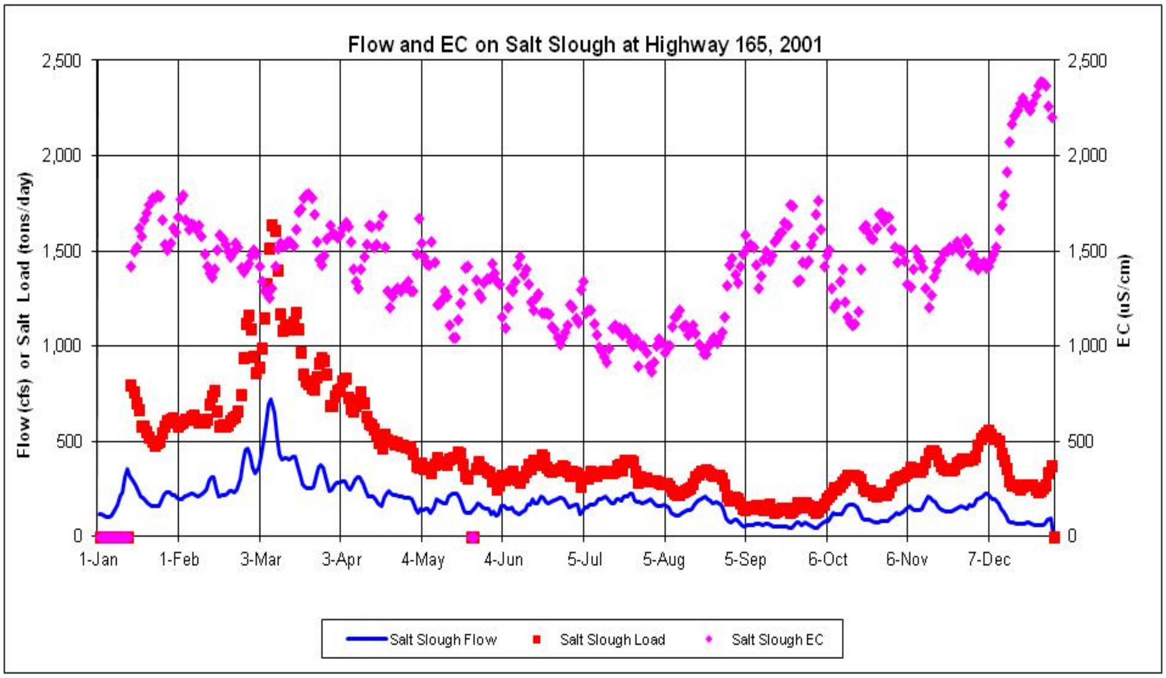


Figure F.2-3b. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in Salt Slough at Highway 165 during 2001

Figure F.2-3c shows the daily flow and EC, with the calculated salt load (tons/day) for Mud Slough for 2001. The maximum flows in 2001 were about 400 cfs in early March when many wetlands are drained following duck season. The spring and summer flows were about 50cfs, and the fall flows were about 100 cfs. The San Luis Drain discharge flow is shown for comparison; the San Luis drain is the major source of flow in spring and summer. The Mud Slough EC measurements in 2001 were about 2,000–4,000 µS/cm throughout the year, with the lowest values when flows were about 100 cfs or more. The EC in the San Luis Drain was generally 4,000–5000 µS/cm. The salt load in Mud Slough in 2001 was about 500 tons/day through most of 2001. The salt loads were about 1,000 tons/day in January and February (higher flows) and were about 250 tons/day in September. The flow, EC measurements, and resulting salt load pattern were comparatively uniform through the year in Salt Slough. Salt and Mud Sloughs represent the major sources of salt load upstream of the Merced River; each contributes about 250–1,000 tons/day to the SJR.

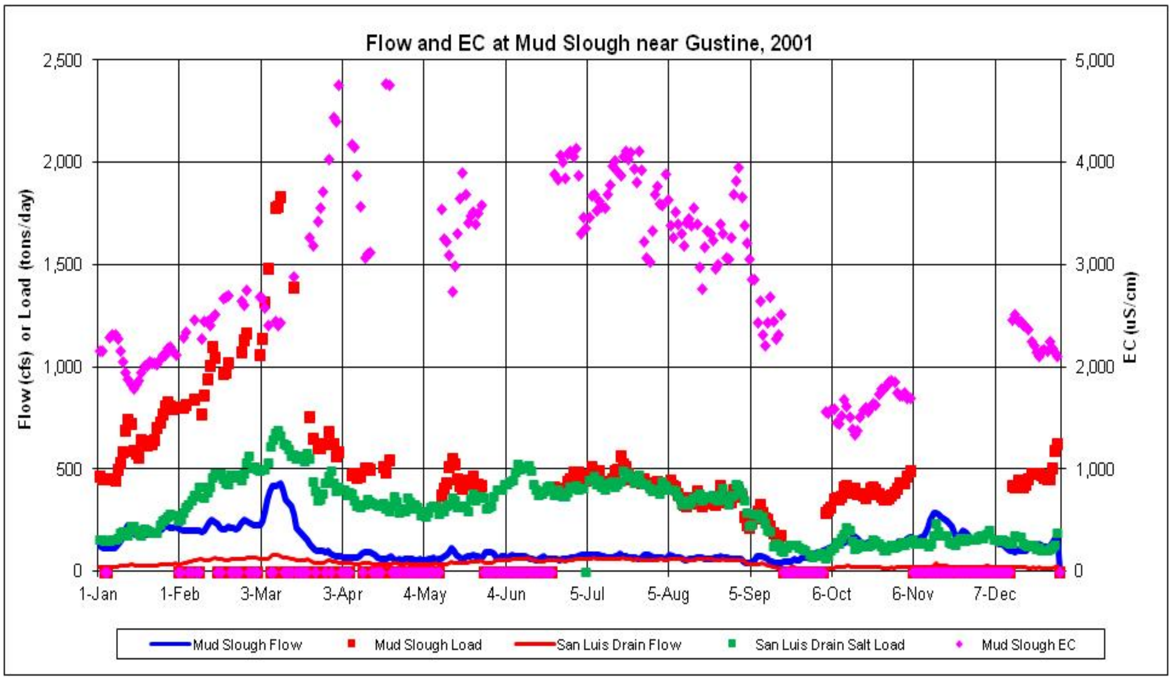


Figure F.2-3c. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in Mud Slough near Gustine and in the San Luis Drain Discharge to Mud Slough during 2001

Figure F.2-3d shows the daily flow and EC, with the calculated salt load (tons/day) for the Merced River for 2001. The maximum flows in 2001 were about 1,250 cfs (VAMP flow releases) in April and May. Merced River flows were about 300 cfs in January–May, decreasing to about 100 cfs in July–September, and increased to 500 cfs in October–December for the fish pulse flow in late October and hydropower generation and flood control storage releases. The flows near Cressy (upstream) and at Stevinson (downstream) were very similar throughout the year. The Merced River EC measurements were 100–200 μS/cm in winter and reduced to 50 μS/cm during the VAMP pulse flows and the October pulse flow (for fish). The EC was about 200–300 μS/cm during summer low flows. The Merced River salt load in 2001 was about 50–100 tons/day throughout the year.

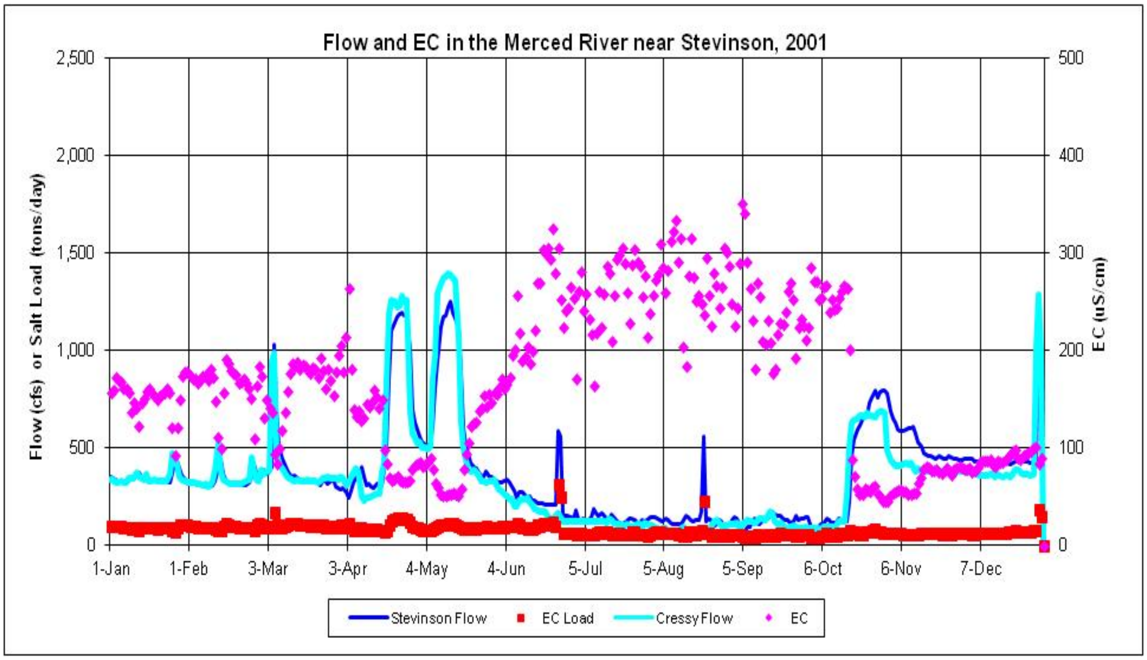


Figure F.2-3d. Daily Measured Flow (cfs) and EC (μS/cm) and Calculated Salt Load (tons/day) in the Merced River near Stevinson during 2001

Figure F.2-3e shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Crows Landing (downstream of Merced River) for 2001. The Merced River flows are shown for comparison. The SJR flows at Crows Landing were generally 500–1,000 cfs in most months without a flood event (i.e., March). The Crows Landing EC was reduced to 500 µS/cm during higher flows (1,000 cfs) and were about 2,000–4,000 tons/day in winter and spring. The salt loads were 1,000 tons/day in summer and were about 2,000 tons/day at the end of 2001. Because the Merced River salt loads were generally 50–100 tons/day, the great majority of the salt load in the SJR at Crows Landing originated from upstream of the Merced River.

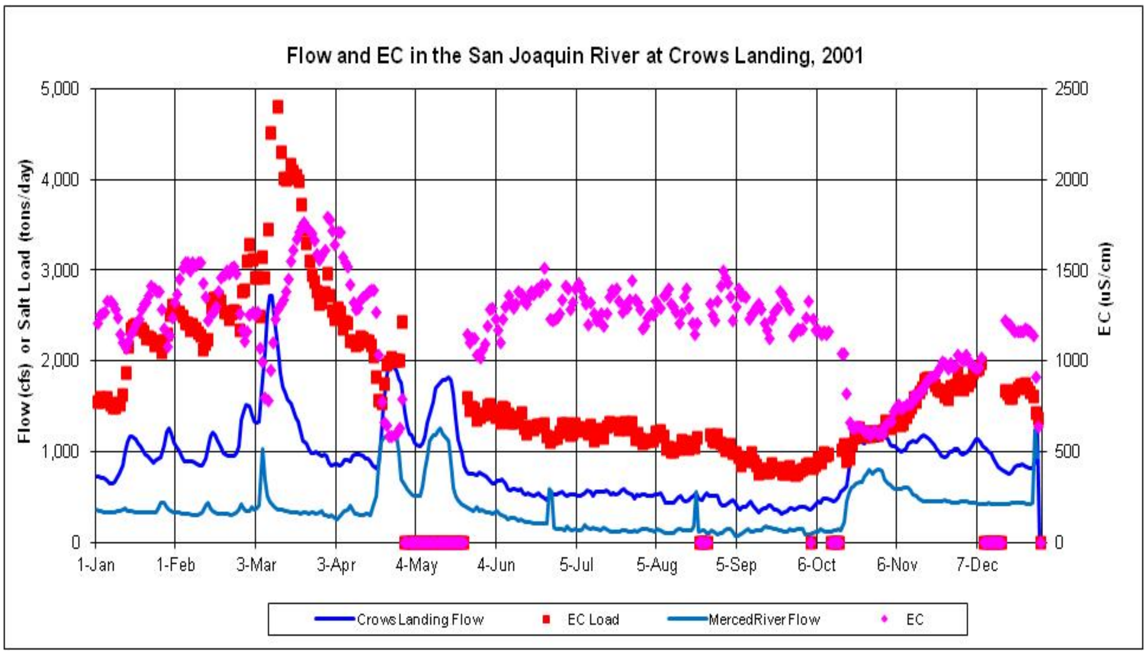


Figure F.2-3e. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Crows Landing (downstream of the Merced River) during 2001

Figure F.2-3f shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Maze (downstream of Tuolumne River) for 2001. The Tuolumne River flows are shown for comparison. The SJR flows at Maze were about 2,000 cfs in winter, increased to 5,000 cfs at the end of February, and were about 3,000 cfs during the VAMP period. Flows at Maze were 1,000 cfs from June–September, increased to 2,000 cfs during the late October peak, and were 1,500 cfs at the end of 2001. The Tuolumne River flow was about 500 cfs for winter, about 1,000 cfs during VAMP, and about 250 cfs from June through the end of 2001. The Maze EC estimates in 2001 were about 1,000 µS/cm in January, but were reduced to 500 µS/cm during higher flows in February–March and during VAMP. The estimated Maze EC values were 1,000 µS/cm for summer and fall and were 500 µS/cm during the October pulse flow. The Tuolumne River flow provided some dilution (10–25 percent of the SJR flow at Maze) of the EC measured at Crows Landing. There were some agricultural diversions between Crows Landing and Maze, and additional inflows to the SJR from agricultural drainage and shallow groundwater seepage to the river, so that salt loads at Maze were higher than at Crows Landing. The SJR at Maze salt loads in 2001 were about 3,000 tons/day in January and February, increased to 5,000 tons during March, were 2,000 tons/day in May, were about 1,500 tons/day during June–September, and were about 2,500 tons/day in November and December.

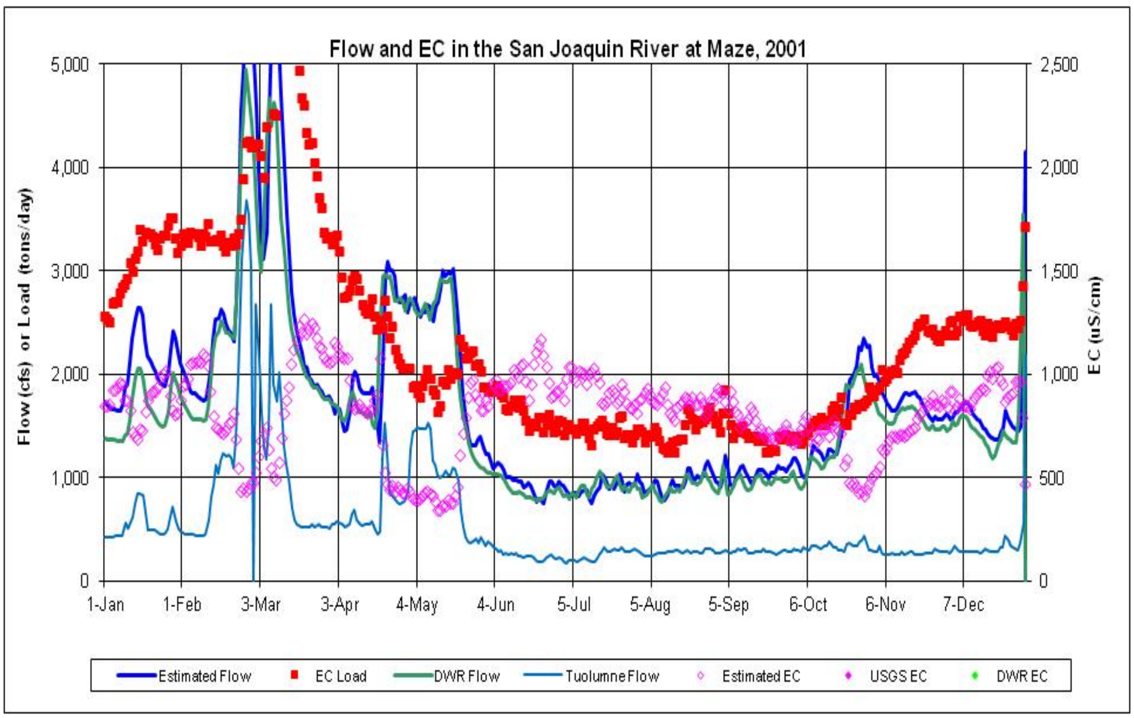


Figure F.2-3f. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Maze (downstream of the Tuolumne River) during 2001

Figure F.2-3g shows the daily flow and EC, with the calculated salt load (tons/day) for the Stanislaus River for 2001. The flows were about 400–500 cfs in winter, increased to 1,500 cfs during the VAMP period from mid-April to mid-May, were 500 cfs in June and July, and declined to about 300 cfs in October, prior to the pulse flow of 1,000 cfs for a week in mid-October. The flows at Goodwin (upstream) and at Ripon (downstream) were very similar in 2001. The Stanislaus River EC was about 150 μS/cm in winter, was reduced to 75 μS/cm during the VAMP period (1,500 cfs), and gradually increased to 125 μS/cm at the end of 2001. The Stanislaus River salt loads in 2001 were 50–100 tons/day.

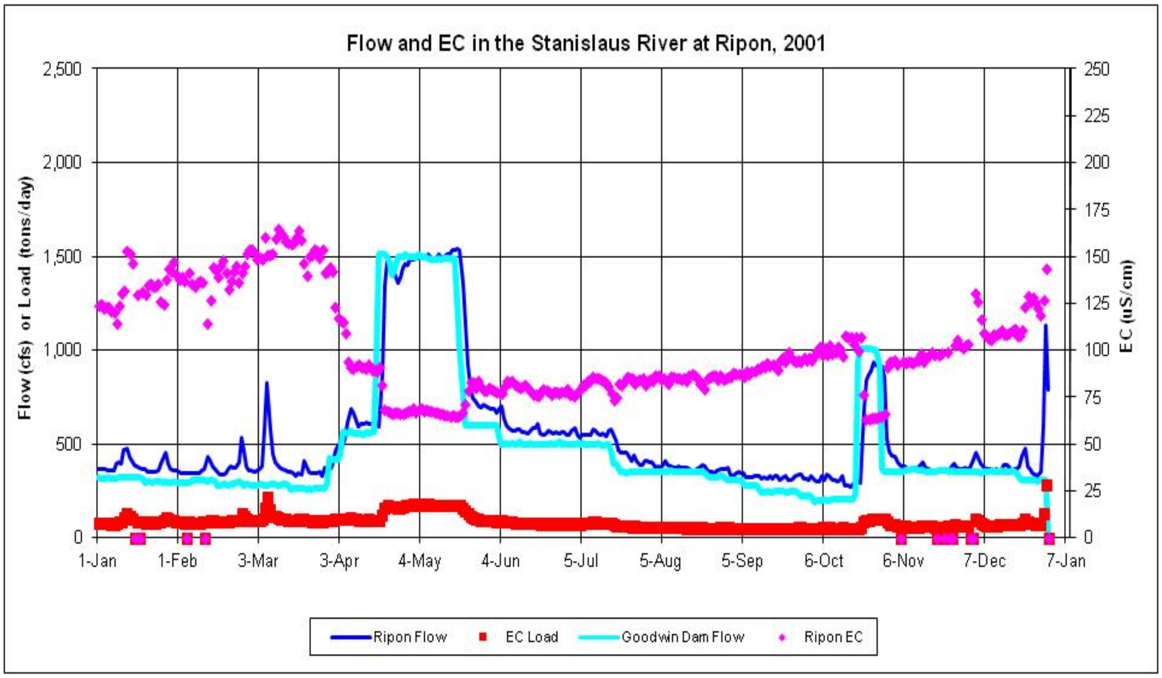


Figure F.2-3g. Daily Measured Flow (cfs) and EC (μS/cm) and Calculated Salt Load (tons/day) in the Stanislaus River at Ripon during 2001

Figure F.2-3h shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Vernalis (downstream of Stanislaus River) for 2001. The Stanislaus River flows are shown for comparison. The SJR flows at Vernalis were 2,000–3,000 cfs in January–February and were about 5,000 cfs for a two-week period in late February and early March. The flow was 4,000 cfs during VAMP and decreased to about 1,500 cfs from June through mid-October. The October pulse flow was 3,000 cfs and was 2,000 cfs in November and December. The Vernalis EC measurements in 2001 were about 750 μS/cm in January and February, but were reduced to 500 μS/cm during higher flows in February–March, and were reduced to 250 μS/cm during VAMP and the October pulse. The Vernalis EC values ranged from 500–750 μS/cm during the remainder of summer and fall, generally following a flow-dilution relationship. The SJR at Vernalis salt loads in 2001 were 3,000 tons/day in January and February, increased to 4,000 tons/day in March (runoff), reduced to 2,000 tons/day during VAMP, ranged from 1,500 tons/day from June–October, and were 2,500 tons/day in November and December. The monthly average Vernalis EC values approached the EC objective (700 μS/cm) during June–August, and the Stanislaus flows in June–August may have been increased for salinity control.

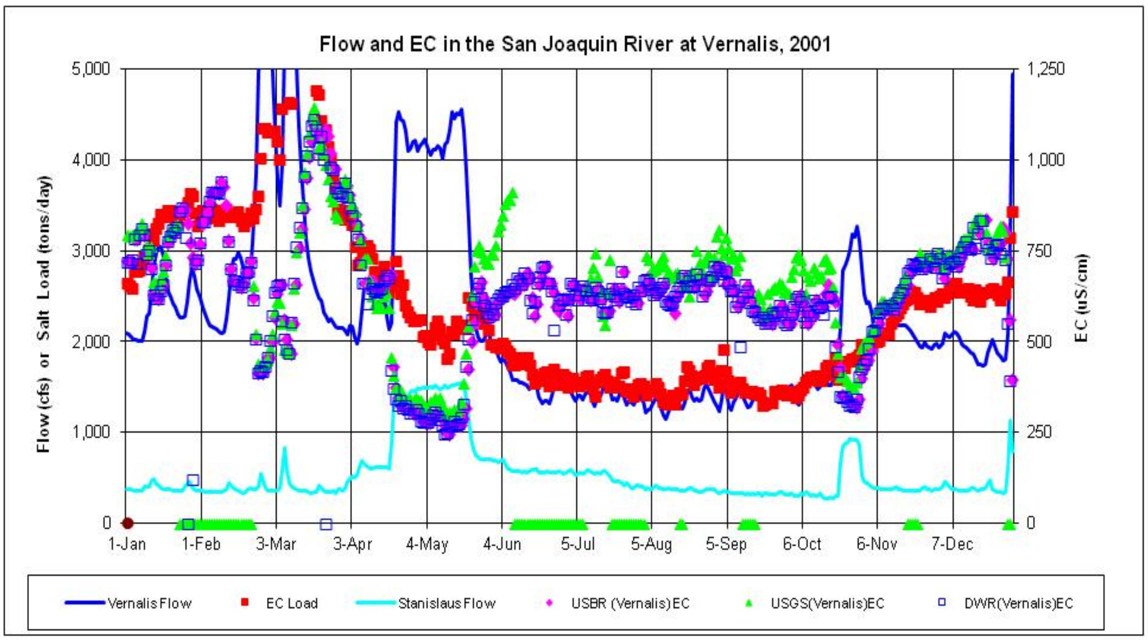


Figure F.2-3h. Daily Measured Flow (cfs) and EC (μS/cm) and Calculated Salt Load (tons/day) in the San Joaquin River at Vernalis during 2001

F.2.3.3 Measured SJR Flow and Salinity in 2002

Figure F.2-4a shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR near Stevinson for 2002. The flows in 2002 were extremely low; flows remained less than 50 cfs except for two short storms (January and December). Flows were less than 25 cfs from April through December. The EC measurements in the SJR at Stevinson were about 1,500–2,000 μS/cm most of the year (flows of about 25cfs) and were reduced to less than 500 μS/cm when flows increased to 100 cfs or more. The salt load was 50–200 tons/day in winter and was less than 25 tons/day for most of the year with flows of less than 25 cfs.

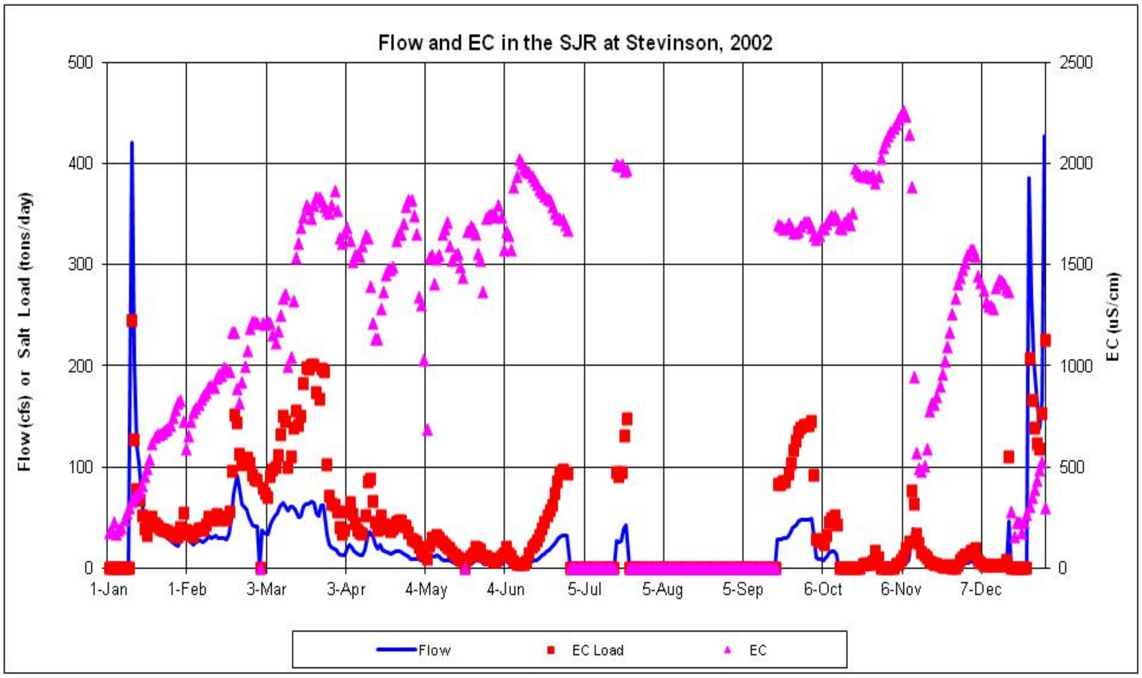


Figure F.2-4a. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Stevinson during 2002

Figure F.2-4b shows the daily flow and EC, with the calculated salt load (tons/day) for Salt Slough for 2002. The maximum flows were about 250 cfs in March and December and were 100–200 cfs from April–November. Salt Slough EC measurements in 2002 were about 2,000 µS/cm in January, 1,500 µS/cm in February–May, and 1,000–1,500 µS/cm for the remainder of the year. The salt load in Salt Slough was 500–1,000 tons/day in winter, was 250–500 tons/day in spring, summer, and fall, and increased to 1,000 tons/day at the end of December 2002. The monthly salt loads were lowest in summer.

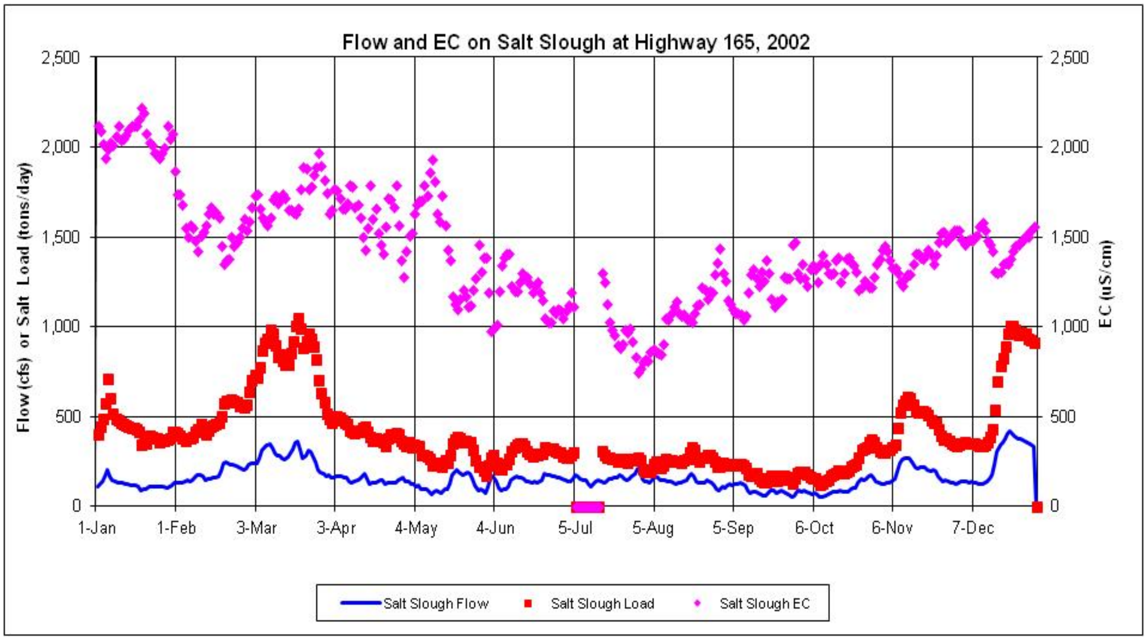


Figure F.2-4b. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in Salt Slough at Highway 165 during 2002

Figure F.2-4c shows the daily flow and EC, with the calculated salt load (tons/day) for Mud Slough for 2002. The flows in 2002 were about 100cfs in winter, were 50 cfs in spring and summer, and increased to 100–500 cfs in fall (water deliveries to the wetlands). The San Luis Drain discharge flow is shown for comparison; the San Luis drain is the major source of flow in spring and summer. The Mud Slough EC was about 2,000–5,000 µS/cm throughout the year, with the lowest values when flows were about 100 cfs or more. The salt loads in Mud Slough in 2002 were about 250–500 tons/day through most of 2002. The salt loads were about 500–1,000 tons/day in winter and in November–December. The flow, EC measurements, and resulting salt load pattern were comparatively uniform through the year in Salt Slough. Salt and Mud Sloughs represent the major sources of salt load upstream of the Merced River; each contributes about 250–1,000 tons/day to the SJR.

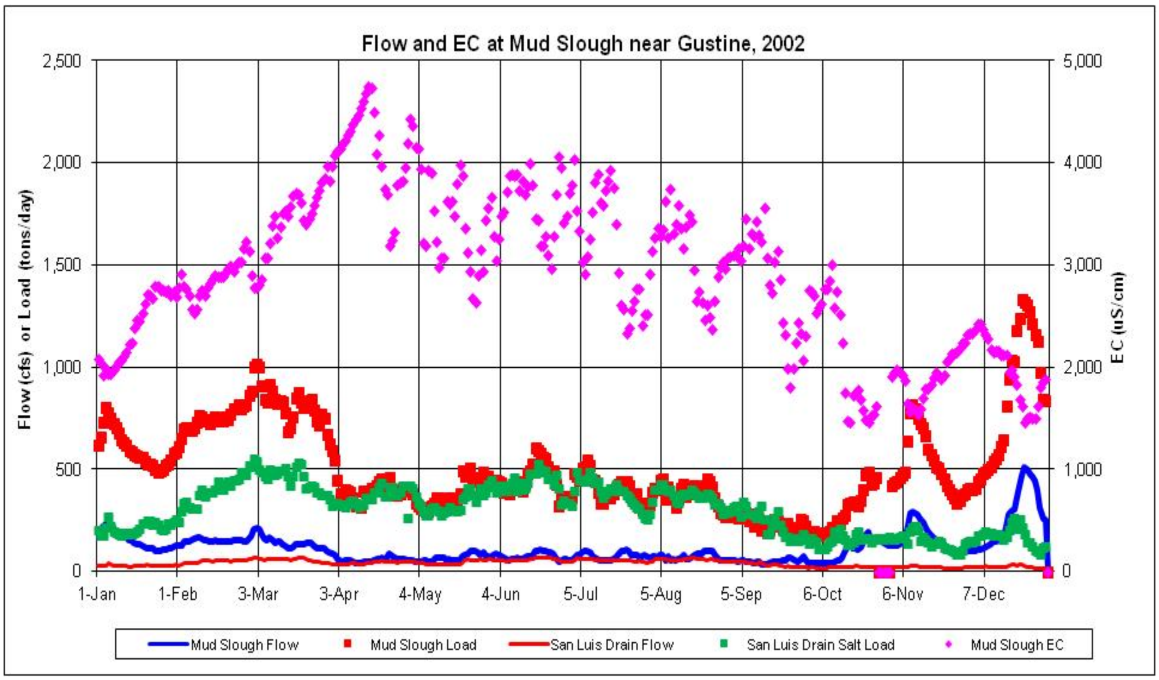


Figure F.2-4c. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in Mud Slough near Gustine and in the San Luis Drain Discharge to Mud Slough during 2002

Figure F.2-4d shows the daily flow and EC, with the calculated salt load (tons/day) for the Merced River for 2002. The Merced River flows were about 250 cfs in winter and increased to about 1,250 cfs during VAMP. Summer flows were about 50 cfs, the October pulse flow was 750 cfs, and November–December flows were 250 cfs (fish flow requirement). The flows near Cressy (upstream) and at Stevinson (downstream) were very similar throughout 2002. The Merced River EC measurements were 100–200 µS/cm in winter and were reduced to 50 µS/cm during the VAMP pulse flows and the October pulse flow. The EC was about 200–400 µS/cm during summer low flows. The Merced River salt load in 2002 was about 25–50 tons/day throughout the year.

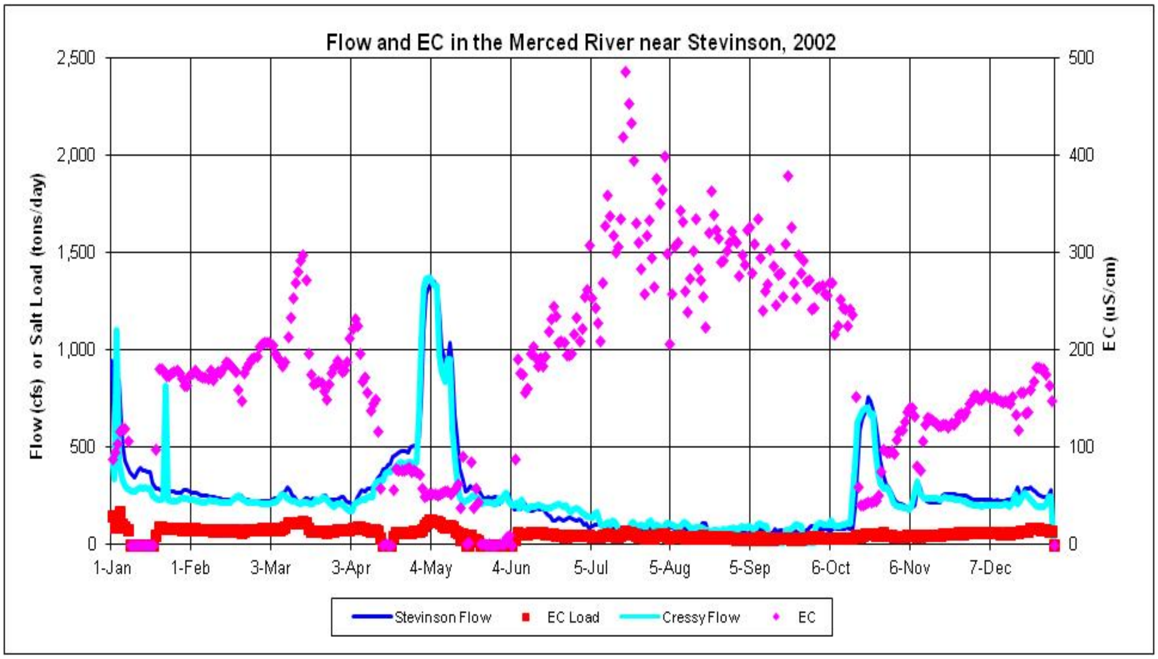


Figure F.2-4d. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the Merced River near Stevinson during 2002

Figure F.2-4e shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Crows Landing for 2002. The Merced River flows are shown for comparison. The SJR flows at Crows Landing were generally 500–1,000 cfs in most months without a flood event (i.e., January and December). Because the Merced River contributes about 25 to 50 percent of the SJR flow at Crows Landing, the maximum EC measurements of 1,000–2,000 μS/cm were less than the EC measured in the SJR at Stevinson or in Mud and Salt Sloughs. The Crows Landing EC measurements were reduced to 500 μS/cm during the higher Merced River flows in April and October of 2002. The SJR at Crows Landing salt loads were about 2,000–3,000 tons/day in winter and spring, were 1,000 tons/day in summer, and were about 2,000 tons/day at the end of 2002. Because the Merced River salt loads were 25–50 tons/day, the great majority of the salt load in the SJR at Crows Landing originated from upstream of the Merced River.

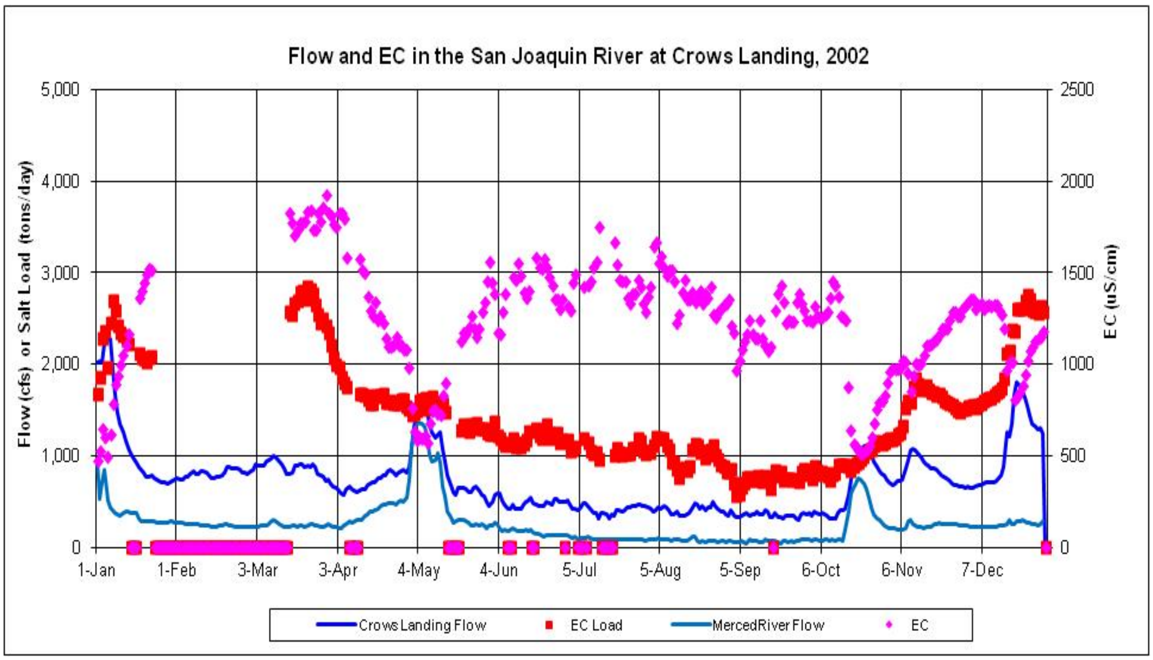


Figure F.2-4e. Daily Measured Flow (cfs) and EC (μS/cm) and Calculated Salt Load (tons/day) in the SJR at Crows Landing (downstream of the Merced River) during 2002

Figure F.2-4f shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Maze for 2002. The Tuolumne River flows are shown for comparison. The SJR flows at Maze were about 5,000 cfs at the beginning of January, but were about 1,500 cfs in winter, and were about 2,500 cfs during VAMP. Flows at Maze were 750–1,000 cfs from June–September, increased to 1,500 cfs during the late October peak, and were 2,000 cfs at the end of December 2002. The Tuolumne River flow was about 250 cfs for winter, about 1,000 cfs during VAMP, and about 250 cfs from June through the end of 2002. The Maze EC estimates in 2002 were about 1,000–1,500 µS/cm in winter and 750–1,250 µS/cm during summer, but were reduced to 500 µS/cm during higher flows in early January, during VAMP, and during the October pulse flow. The SJR at Maze salt loads in 2002 were about 3,000 tons/day in winter, were about 1,500 tons/day in spring, were 1,000 tons/day in summer, and increased from 1,000 tons/day to 3,000 tons/day in fall. The salt loads at Maze were 250–500 tons/day higher than the salt load at Crows Landing, although the Maze EC was less than at Crows Landing EC.

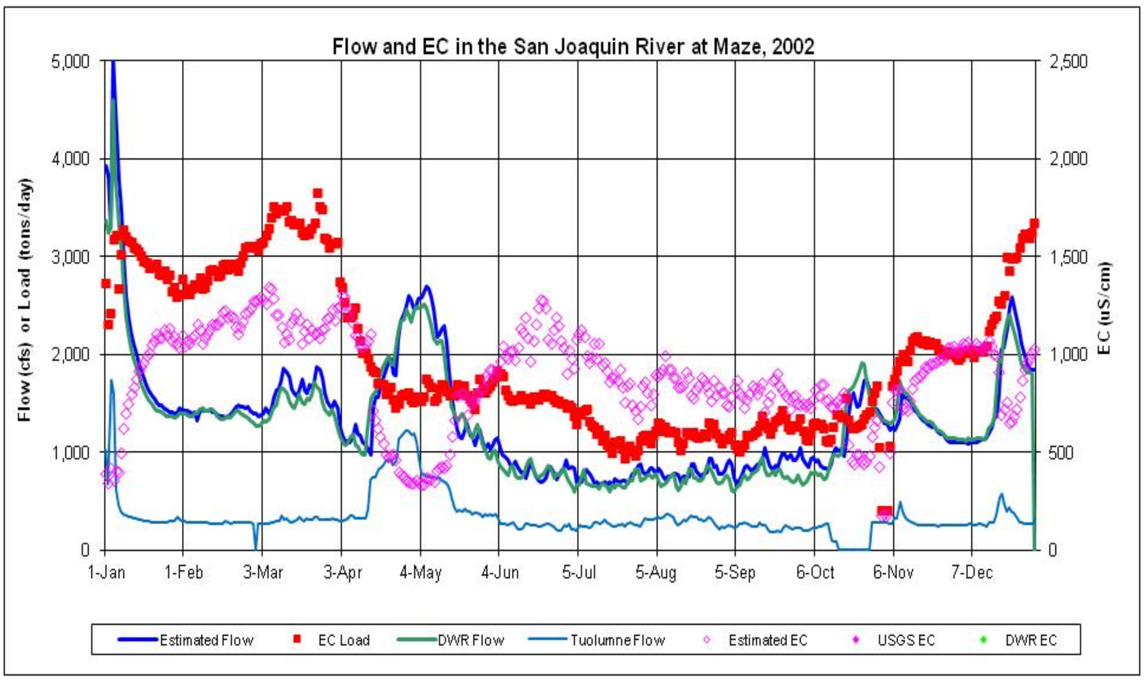


Figure F.2-4f. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Maze (downstream of the Tuolumne River) during 2002

Figure F.2-4g shows the daily flow and EC, with the calculated salt load (tons/day) for the Stanislaus River for 2002. The flows were about 250–500 cfs in winter, increased to 1,000–1,500 cfs during the VAMP period of April and May, were 500 cfs in June and July, and declined to about 300 cfs in October, prior to the pulse flow of 600 cfs for a week in late-October. The Stanislaus River EC was about 150 µS/cm in January, was 100 µS/cm in February and March, reduced to 75 µS/cm during VAMP, and gradually increased to 125 µS/cm at the end of 2002. The Stanislaus River salt loads in 2002 were 25–50 tons/day.

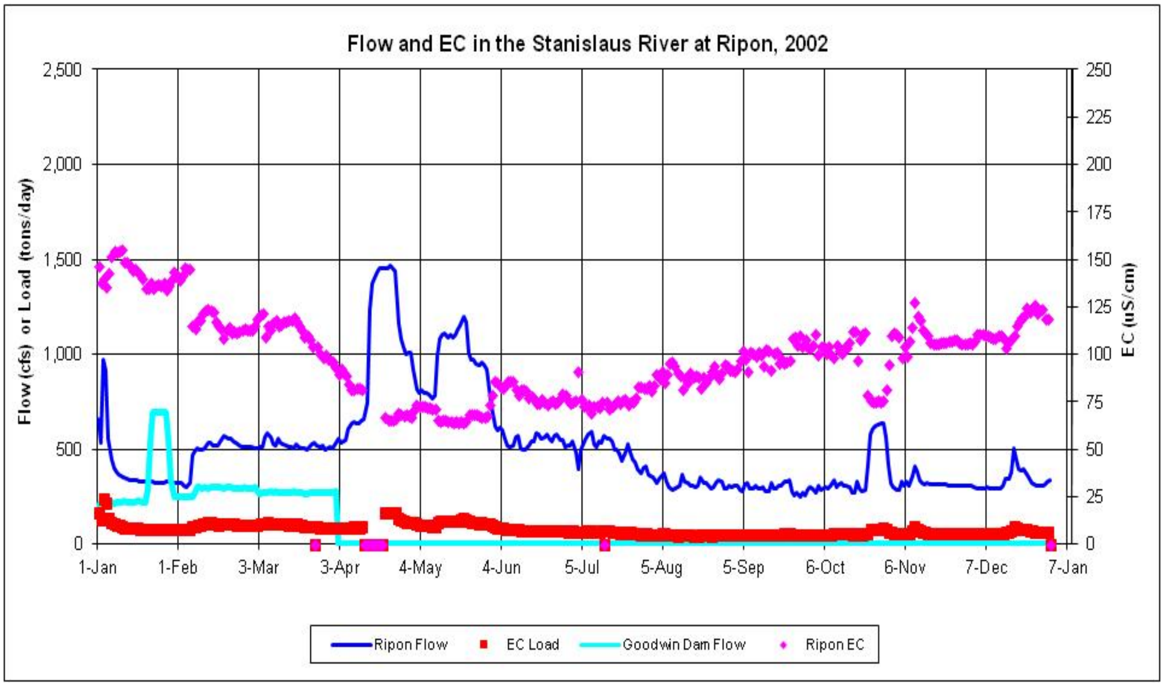


Figure F.2-4g. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the Stanislaus River at Ripon during 2002

Figure F.2-4h shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Vernalis (downstream of Stanislaus River) for 2002. The Stanislaus River flows are shown for comparison. The SJR flows at Vernalis were 5,000 cfs at the beginning of January, about 2,000 cfs in February and March, about 3,000 cfs during VAMP, 1,000–1,500 cfs from June–October, 2,000 cfs in the October pulse, and about 2,500 cfs during the December storm. The Vernalis EC measurements in 2002 were about 900 µS/cm in January–March and reduced to 250 µS/cm during VAMP and the October pulse. The Vernalis EC values ranged from 500–750 µS/cm during the remainder of summer and fall. The SJR at Vernalis salt loads in 2002 were 3,000 tons/day in winter, were reduced to 2,000 tons/day during April and May, were 1,000–1,500 tons/day from June–October, were 2,000 tons/day in November, and increased to 3,000 tons/day at the end of 2002. The monthly average Vernalis EC values approached the EC objective of 1,000 µS/cm during winter (January–March) and approached the EC objective of 700 µS/cm during summer (June–August). Higher releases from New Melones (greater than the 250 cfs fish flow) for salinity control were apparently made in February–March and June–July 2002.

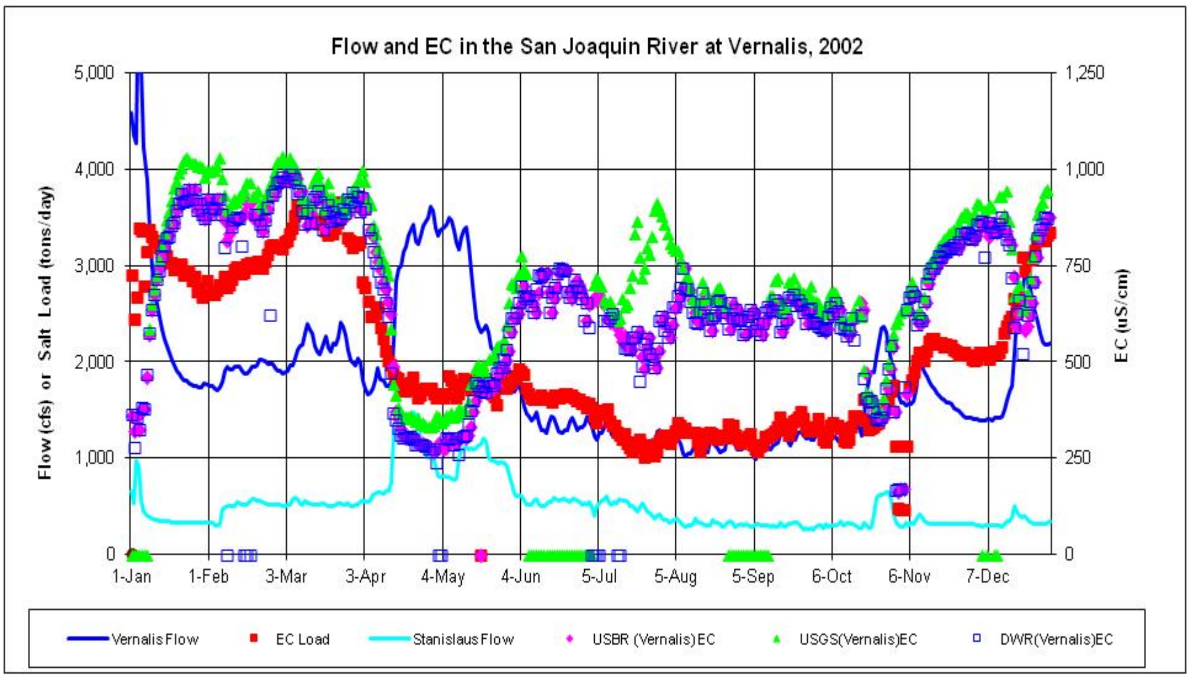


Figure F.2-4h. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the San Joaquin River at Vernalis during 2002

F.2.3.4 Measured SJR Flow and Salinity in 2003

Figure F.2-5a shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR near Stevinson for 2003. The flows in 2003 were again very low; flows remained less than 25 cfs except for two short storms (January and March). The SJR at Stevinson EC was about 1,500–2,000 µS/cm most of the year (flows of about 25cfs) but was reduced to less than 1,000 µS/cm when flows increased to 50 cfs or more. The salt loads were 100–200 tons/day in winter (with runoff) and were less than 25 tons/day for most of the year with flows of less than 25 cfs.

Figure F.2-5b shows the daily flow and EC, with the calculated salt load (tons/day) for Salt Slough for 2003. The maximum flows were about 500 cfs in March and 100–200 cfs from April–December.

The Salt Slough EC in 2003 was about 1,500–2,000 µS/cm in winter, 1,000–1,500 µS/cm in spring and summer, and 2,000 µS/cm in December. The salt loads in Salt Slough were 500–1,500 tons/day in winter and were 250–500 tons/day in spring, summer, and fall. The monthly salt loads in Salt Slough were lowest in summer.

Figure F.2-5c shows the daily flow and EC, with the calculated salt load (tons/day) for Mud Slough for 2003. The flows in 2003 were about 200 cfs in winter, were 50 cfs in spring and summer, and increased to 200 cfs in fall (water deliveries to the wetlands). The San Luis Drain discharge flow is the major source of flow in spring and summer. The Mud Slough EC was about 1,500–4,000 µS/cm throughout the year, with EC values of less than 2,000 µS/cm when flows were about 100 cfs or more. The salt loads in Mud Slough in 2003 were about 250–500 tons/day through most of 2003. The salt loads were about 1,000 tons/day in February–March. Salt and Mud Sloughs represent the major sources of salt load upstream of the Merced River; each contributes about 250–1,000 tons/day to the SJR.

Figure F.2-5d shows the daily flow and EC, with the calculated salt load (tons/day) for the Merced River for 2003. The Merced River flows were about 200 cfs in winter and increased to about 500–1,500 cfs during VAMP. Summer flows were about 50–100 cfs, the October pulse flow was 500 cfs, and the November–December flows were about 200 cfs (fish flow requirement). The flows near Cressy and at Stevinson were very similar throughout 2003. The Merced River EC measurements were 150–200 µS/cm in winter and reduced to 50 µS/cm during the VAMP pulse flows and the October pulse flow. The EC was about 200–400 µS/cm during summer low flows. The Merced River salt load in 2003 was about 25–50 tons/day throughout the year.

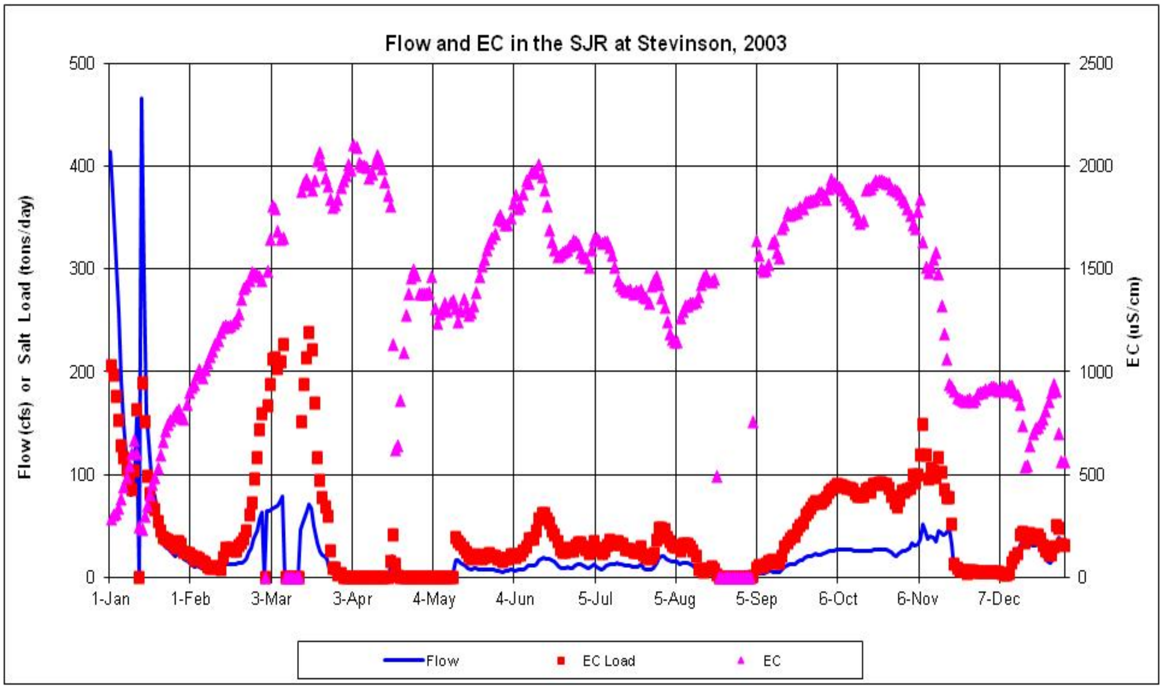


Figure F.2-5a. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Stevinson during 2003

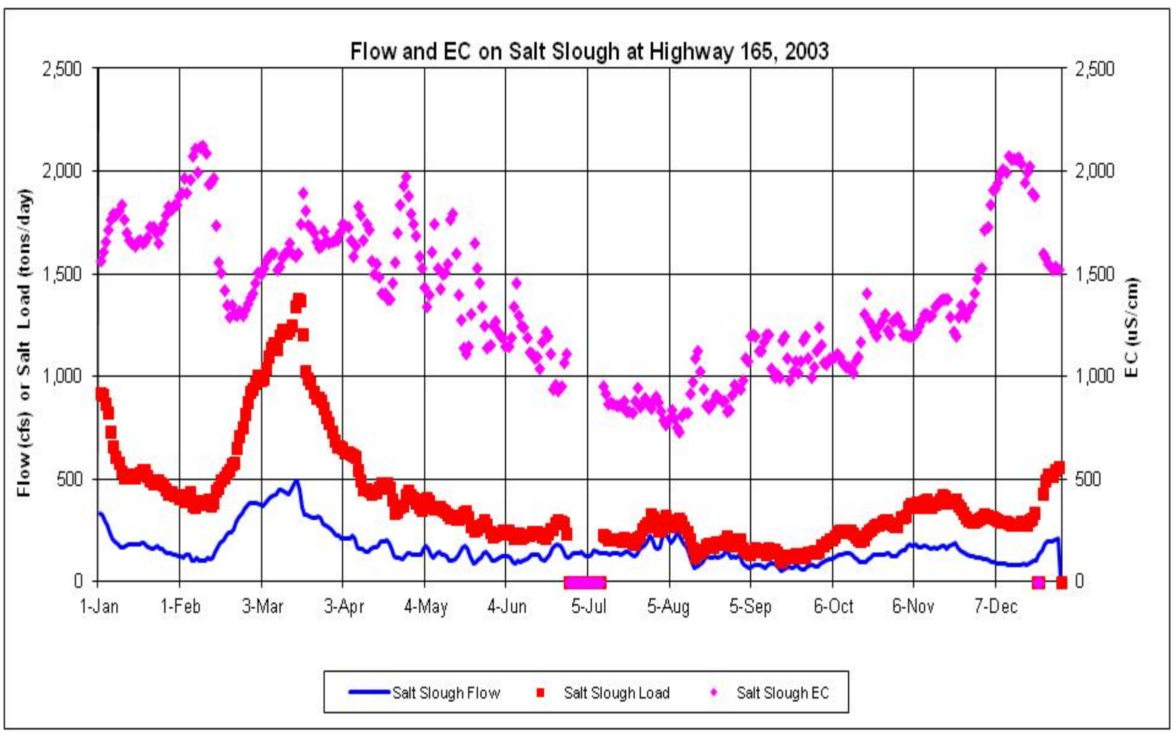


Figure F.2-5b. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in Salt Slough at Highway 165 during 2003

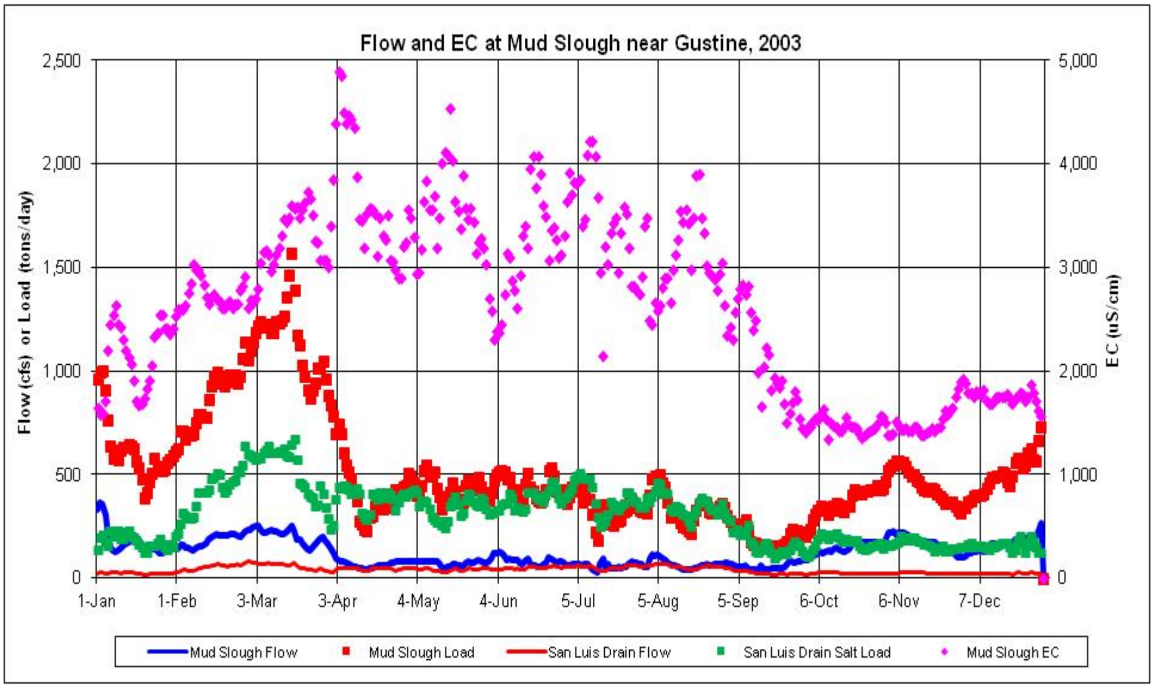


Figure F.2-5c. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in Mud Slough near Gustine and in the San Luis Drain Discharge to Mud Slough during 2003

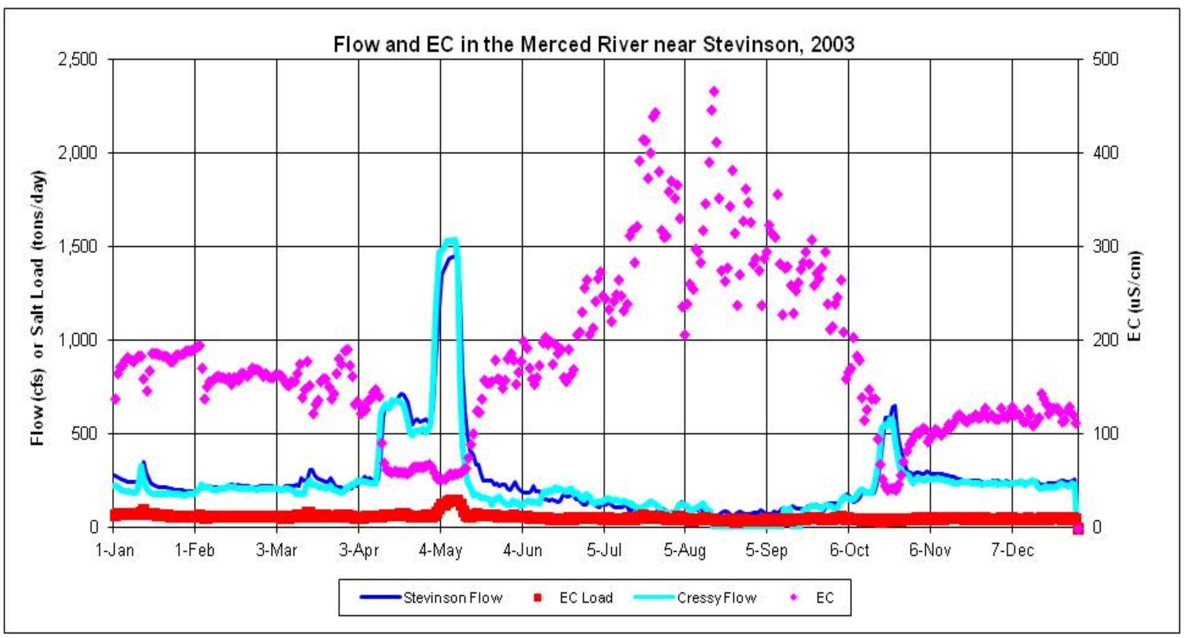


Figure F.2-5d. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the Merced River near Stevinson during 2003

Figure F.2-5e shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Crows Landing for 2003. The Merced River flows are shown for comparison. The SJR flows at Crows Landing were generally 1,000 cfs in winter and spring, 1,750 cfs in early May, less than 500 cfs in summer, and 750 cfs in fall. The Crows Landing EC was about 1,500 µS/cm in winter, reduced to 1,000 µS/cm during VAMP, and was 1,000–1,500 µS/cm in summer and fall. The Crows Landing EC was reduced to 500 µS/cm during higher Merced River flows in May and October of 2003. The SJR at Crows Landing salt loads were about 2,000–3,000 tons/day in winter, 1,000–2,000 tons/day in spring, 1,000 tons/day in summer, and about 2,000 tons/day at the end of 2003. Because the Merced River salt loads were 25–50 tons/day, the great majority of the salt load in the SJR at Crows Landing originated from upstream of the Merced River.

Figure F.2-5f shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Maze for 2003. The Tuolumne River flows are shown for comparison. The SJR flows at Maze were about 1,500 cfs in winter, 2,000 cfs during VAMP, and 1,000 cfs in summer and fall, with an October pulse flow of 1,500 cfs. The Tuolumne River flow was about 250 cfs for winter, about 750–1,000 cfs during VAMP, and about 200–300 cfs from June through the end of 2003. The Maze EC estimates in 2003 were about 1,250 µS/cm in winter and 750–1,250 µS/cm during summer, but were reduced to 500 µS/cm during VAMP and the October pulse flow. The SJR at Maze salt loads in 2003 were about 3,000–4,000 tons/day in winter, about 2,000 tons/day in spring, 1,500 tons/day in summer, and 2,000 tons/day in fall. The salt loads at Maze were 250–500 tons/day higher than the salt load at Crows Landing, although the Maze EC was less than at Crows Landing EC.

Figure F.2-5g shows the daily flow and EC, with the calculated salt load (tons/day) for the Stanislaus River for 2003. The flows were about 250–500 cfs in winter, increased to 750–1,500 cfs during the extended VAMP period of April–June, were 400 cfs in July, and were about 300 cfs from August–December, with a pulse flow of 1,000 cfs in mid-October. The Stanislaus River EC was about 150 µS/cm in January, was 100 µS/cm in February and March, reduced to 75 µS/cm during VAMP, and gradually increased to 125 µS/cm at the end of 2003. The Stanislaus River salt loads in 2003 were 25–50 tons/day.

Figure F.2-5h shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Vernalis for 2003. The Stanislaus River flows are shown for comparison. The SJR flows at Vernalis were 2,000 cfs in winter and spring, with a VAMP flow of 3,000 cfs. Flows were about 1,500 cfs in summer and fall with an October pulse flow of 2,500 cfs. The Vernalis EC measurements in 2003 were about 1,000 µS/cm in January–March and reduced to less than 500 µS/cm during VAMP and the October pulse. The Vernalis EC values ranged from 500–750 µS/cm during the remainder of summer and fall. The SJR at Vernalis salt loads in 2003 were 3,000–4,000 tons/day in winter, reduced to 2,000 tons/day during April and May, and were 1,500–2,000 tons/day from June–December. The monthly average Vernalis EC values approached the EC objective of 1,000 µS/cm during winter (January–March), and approached the EC objective of 700 µS/cm during summer (July–August). Higher releases from New Melones (greater than the 250 cfs fish flow) for salinity control were apparently made in February–March and July–August 2003.

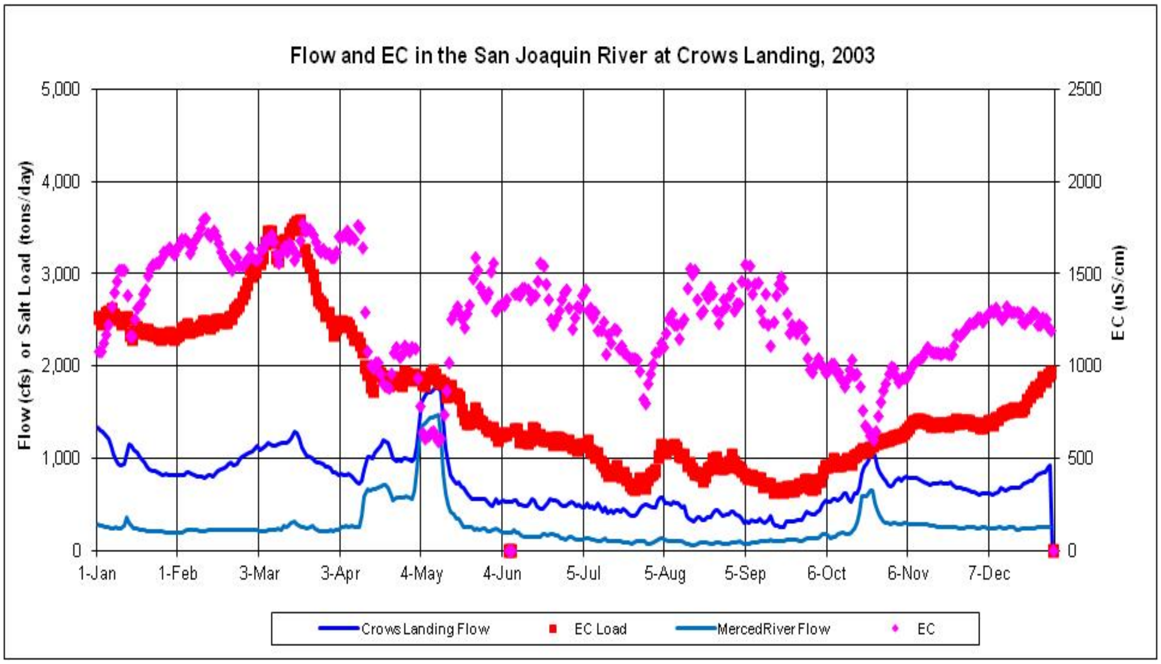


Figure F.2-5e. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Crows Landing (downstream of the Merced River) during 2003

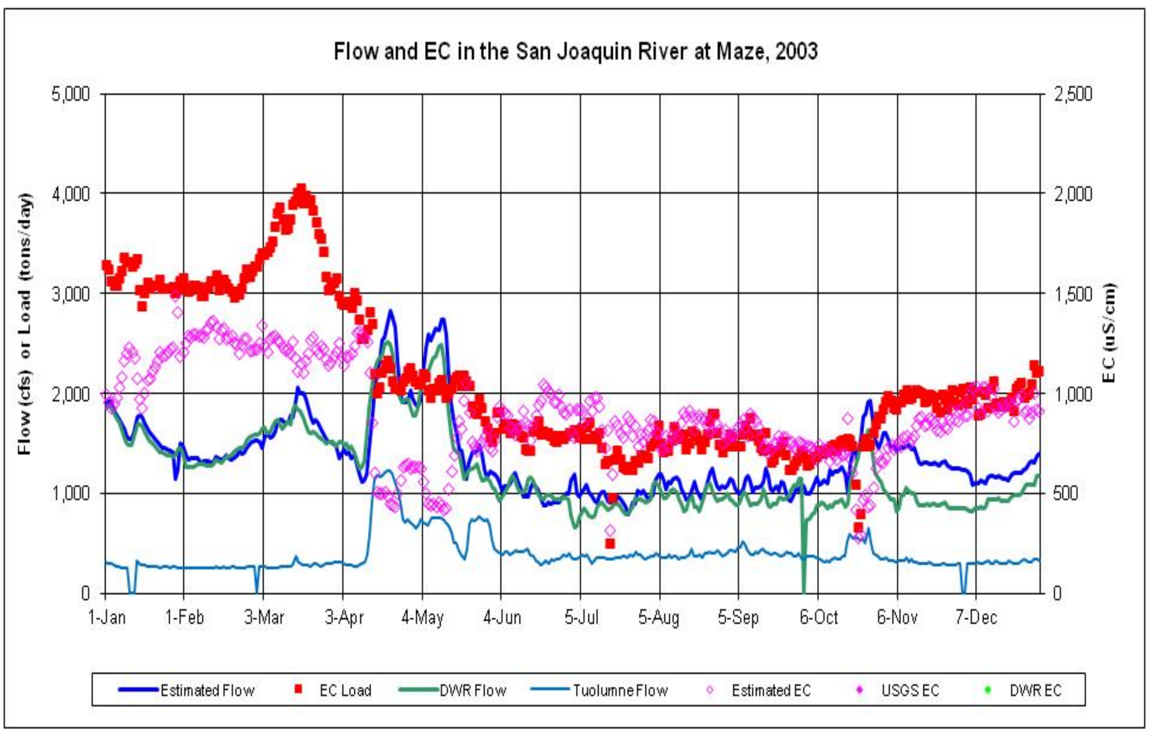


Figure F.2-5f. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Maze (downstream of the Tuolumne River) during 2003

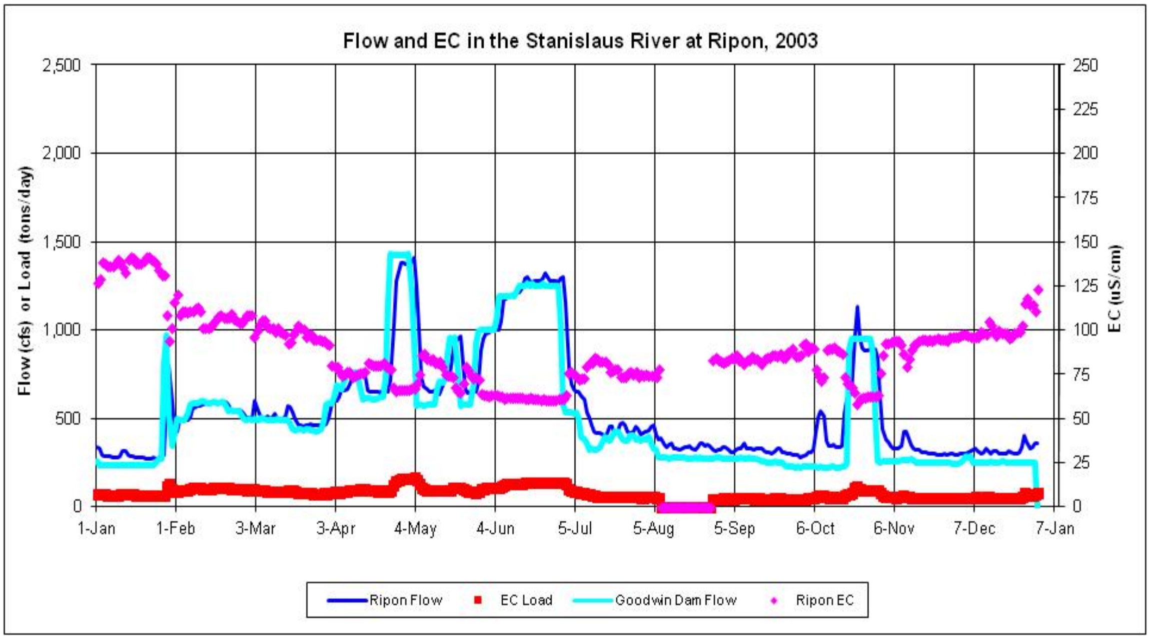


Figure F.2-5g. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the Stanislaus River at Ripon during 2003

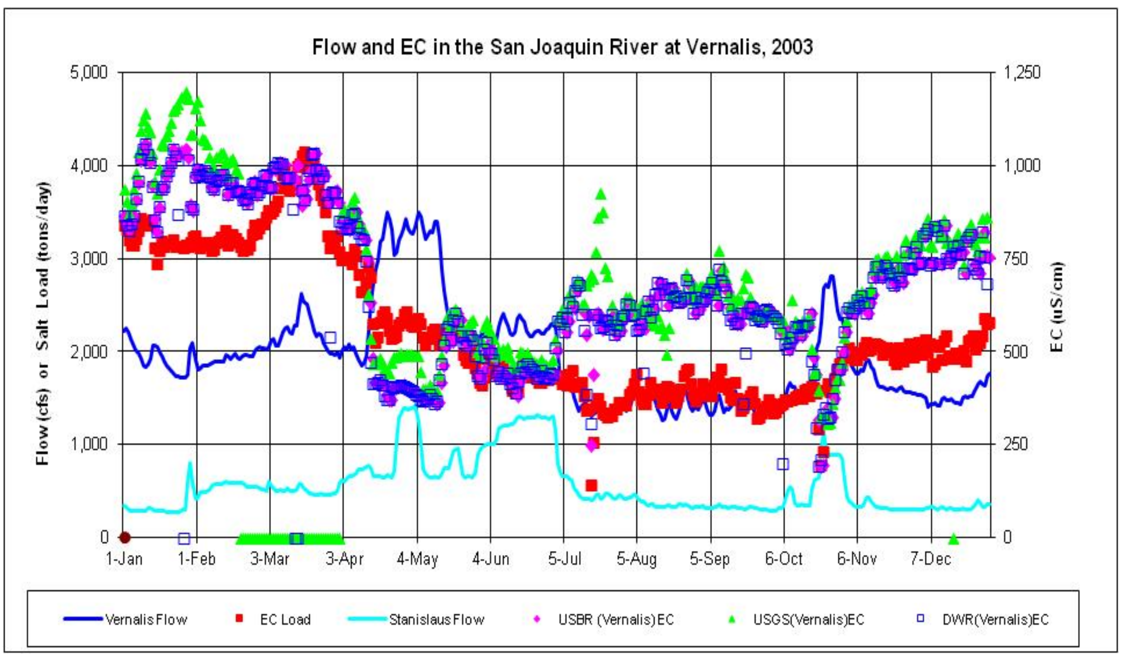


Figure F.2-5h. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the San Joaquin River at Vernalis during 2003

F.2.4 Southern Delta Salinity Patterns

The historical daily river flow and daily EC measurements at Vernalis, Mossdale, Brandt Bridge, Rough and Ready Island, Old River at Union Island, Old River at Tracy Boulevard Bridge, and at the DMC (Central Valley Project [CVP] Jones pumping plant) and the State Water Project (SWP) Banks pumping-plant can be compared to evaluate the sources of increased EC within these southern Delta channels. The distributions of EC values at these locations are shown in Tables F.2-2a through F.2-2h.

Table F.2-2a. Monthly Average Measured SJR at Vernalis EC (µS/cm) for WY 1985–2011 (27 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	262	452	210	128	144	163	128	95	110	152	214	239
10%	310	504	336	338	250	230	200	166	184	320	432	332
20%	398	579	587	490	338	314	276	230	264	473	498	410
30%	414	616	728	534	553	412	351	296	452	541	525	475
40%	476	657	752	639	630	672	470	352	500	586	570	550
50%	507	673	771	752	750	747	535	380	575	611	608	591
60%	524	692	782	778	784	800	570	438	627	633	629	626
70%	584	705	836	815	873	835	643	501	686	693	651	687
80%	696	755	853	945	940	904	695	644	731	758	758	762
90%	768	807	880	1,047	1,104	962	743	692	827	766	797	798
max	866	819	926	1,137	1,299	1,095	1,144	718	871	846	873	898
average	520	661	699	694	695	647	506	413	534	583	600	578

Table F.2-2b. Monthly Average Measured SJR at Mossdale EC (µS/cm) for WY 1985–2011 (27 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	252	396	235	133	146	195	123	96	103	181	237	278
10%	342	580	355	334	236	238	200	177	180	374	438	360
20%	427	600	596	526	332	318	316	249	313	519	512	454
30%	469	651	696	576	555	417	398	338	480	606	584	510
40%	480	674	782	749	594	720	483	359	548	665	602	586
50%	539	703	829	788	773	757	555	417	597	672	671	645
60%	592	727	862	834	876	798	611	481	674	703	705	711
70%	620	732	883	929	907	834	662	578	717	760	748	737
80%	720	775	912	1,001	984	906	733	642	750	801	831	799
90%	794	867	953	1,093	1,153	996	760	700	837	822	873	845
max	892	923	1,007	1,234	1,279	1,090	1,148	782	964	850	935	869
average	554	699	740	744	707	664	530	439	567	635	654	618

Table F.2-2c. Monthly Average Measured SJR at Brandt Bridge EC (µS/cm) for WY 1985–2009 (25 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	240	436	252	150	168	215	154	115	156	243	314	291
10%	337	560	392	424	299	253	228	199	228	356	488	399
20%	401	596	611	526	433	345	335	304	413	548	524	477
30%	467	621	742	574	617	428	397	333	508	609	580	528
40%	504	668	755	672	696	620	562	404	590	676	620	605
50%	530	699	777	772	778	719	636	427	613	695	653	652
60%	601	708	823	800	803	801	659	497	680	709	681	701
70%	659	747	837	863	875	868	686	517	773	739	694	751
80%	722	775	881	968	936	932	733	684	787	777	764	780
90%	808	845	929	1,011	1,047	969	787	734	823	851	801	833
max	941	961	955	1,063	1,213	1,108	827	840	961	888	872	959
average	560	694	734	719	715	662	548	459	593	648	639	631

Table F.2-2d. Monthly Average Measured SJR at Rough and Ready Island (RRI) EC (µS/cm) for WY 1985–2011 (27 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	246	513	301	165	177	175	156	109	126	191	310	289
10%	354	522	389	324	271	260	195	200	199	295	403	377
20%	451	536	633	461	357	348	309	229	313	462	465	444
30%	495	593	709	523	458	391	386	298	480	554	533	483
40%	525	650	743	605	587	497	509	381	524	591	549	554
50%	553	670	793	669	676	643	612	445	573	618	564	578
60%	616	714	818	756	723	739	643	475	629	656	602	614
70%	672	723	839	781	774	805	673	553	656	678	660	661
80%	754	796	867	813	870	861	744	638	707	696	692	751
90%	847	844	900	870	977	955	826	714	751	728	731	805
max	864	966	967	1,028	1,038	1,666	923	849	892	856	791	832
average	577	681	729	641	627	637	542	441	531	576	575	581

Table F.2-2e. Monthly Average Measured Old River at Middle River (Union Island) EC (µS/cm) for WY 1993–2009 (17 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	245	567	271	191	184	225	150	111	123	183	365	282
10%	300	588	536	391	280	278	257	179	195	360	457	396
20%	451	617	661	546	317	324	305	253	367	457	516	432
30%	472	653	759	591	439	402	354	338	514	617	566	503
40%	494	679	795	623	610	455	472	375	537	629	609	555
50%	510	711	818	761	695	682	543	402	565	634	630	588
60%	530	721	839	778	780	802	586	425	570	684	639	606
70%	541	731	864	808	918	873	616	439	639	713	704	650
80%	595	768	876	819	958	947	665	476	675	721	726	693
90%	616	787	890	948	971	1,016	711	517	750	779	732	722
max	660	853	907	1,008	979	1,043	855	649	899	853	918	913
average	491	696	754	679	651	639	501	376	530	610	619	574

Table F.2-2f. Monthly Average Measured Old River at Tracy Boulevard Bridge EC (µS/cm) for WY 1985–2009 (25 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	294	408	355	265	286	245	194	135	240	246	325	295
10%	437	630	646	399	407	339	282	266	245	461	534	512
20%	554	681	714	617	493	376	411	407	463	645	644	597
30%	667	716	756	727	677	467	482	433	569	703	694	626
40%	674	748	831	765	782	685	672	524	625	744	737	692
50%	730	801	870	872	877	906	721	591	697	815	776	761
60%	779	842	901	907	904	950	825	617	786	841	812	816
70%	828	858	928	1,016	1,044	968	858	709	839	904	872	871
80%	875	895	994	1,096	1,094	1,059	954	748	956	931	909	934
90%	1,048	978	1,054	1,167	1,174	1,114	976	778	1,034	985	980	945
max	1,094	1,136	1,246	1,233	1,326	1,174	1,206	1,008	1,210	1,186	1,194	1,541
average	726	798	848	834	827	757	684	562	692	769	771	770

Table F.2-2g. Monthly Average Measured DMC at Jones Pumping Plant EC (µS/cm) for WY 2000–2011 (12 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	290	264	353	258	317	243	186	133	156	206	230	263
10%	339	389	420	284	360	325	202	214	193	238	253	288
20%	359	420	508	484	489	366	339	250	220	241	269	340
30%	416	448	528	496	528	485	388	347	275	255	283	347
40%	436	491	573	520	538	519	398	412	314	281	297	367
50%	472	502	604	540	547	550	425	415	345	297	315	406
60%	489	514	620	548	555	583	454	422	362	304	376	441
70%	501	520	627	618	565	608	485	427	373	312	440	520
80%	506	524	632	647	570	619	507	439	421	318	446	542
90%	535	526	665	763	598	655	521	448	446	351	470	570
max	584	527	756	827	835	665	544	467	522	409	484	580
average	448	467	572	544	536	512	405	362	330	292	352	424

Table F.2-2h. Monthly Average Measured Banks Pumping Plant EC (µS/cm) for WY 1986–2011 (26 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	202	214	269	225	236	258	187	132	143	170	189	212
10%	260	331	384	290	296	287	262	252	190	192	212	244
20%	340	420	477	345	335	318	296	295	215	203	239	292
30%	446	437	512	427	361	327	313	327	288	217	253	316
40%	476	485	549	463	410	391	325	367	324	260	276	365
50%	496	523	593	525	431	449	383	379	367	290	289	429
60%	542	553	602	544	457	473	416	398	389	310	385	490
70%	569	563	659	617	466	482	465	433	432	323	470	531
80%	611	627	713	672	512	514	501	451	442	458	480	602
90%	679	755	817	734	728	541	532	477	588	559	540	658
max	745	816	917	993	814	857	721	718	682	820	790	696
average	488	520	587	519	454	428	396	380	369	332	369	439

These historical flow and EC data provide a very accurate picture of salinity conditions in the southern Delta channels during relatively low flow conditions. Data from 2000–2003 will be evaluated here because these four years were relatively dry, with summer flows of less than 2,000 cfs at Vernalis. In addition, these years represent conditions after the establishment of the 1995 Bay-Delta Plan, which established the southern Delta EC objectives of 700 µS/cm during April–August and 1,000 µS/cm for the rest of the year. The measured EC values at Vernalis during the irrigation season of April–August were approaching the EC objective of 700 µS/cm for several months in each of these years.

The two major sources of water in the southern Delta channels are (1) diversions from the SJR at the head of Old River near Mossdale, and (2) Sacramento River water drawn across the central Delta by the CVP and SWP pumping-plants. The SJR at Vernalis is the primary flow and salinity measurement location for water entering the southern Delta. Although the SJR flow and EC at Vernalis vary daily, there is a general seasonal pattern, because flows are highest during winter and spring while the salt load contributed from groundwater discharge and agricultural drainage may be higher in summer.

F.2.4.1 Effects of Agricultural Diversion and Drainage

There are a number of agricultural diversions along the SJR downstream of Vernalis and in the southern Delta channels. Some of these are major irrigation district diversions, like the Banta–Carbona Irrigation District intake, with a maximum diversion flow of about 175 cfs. Others are small riparian diversion pumps for individual farmers with flows of 5 cfs or less. The diversion of water does not change the salinity of water remaining in the river. However, because downstream river flow is reduced, the effects of all downstream drainage flows or municipal discharges on salinity are greater because of the upstream diversion (i.e., lower flow).

The salt diverted in irrigation water must be returned to the river to maintain acceptable soil salinity, so the net effect of agricultural diversion on downstream river salinity can be estimated from the percentage of river flow diverted. Assuming the diversion is constant and the salt load diverted will be returned to the river, the average effect on downstream salinity can be estimated assuming the same salt load with a reduced downstream flow. However, the increased salinity will not usually be fully observed during the irrigation season, because much of the agricultural drainage of the applied salt will occur during the winter rainfall period, and some salt will enter the shallow groundwater beneath the fields and slowly migrate to the river during the fall, winter, and spring. Nevertheless, the average expected increase in the river EC is proportional to the fraction of water diverted.

F.2.4.2 Effects of Treated Wastewater Discharge

The effect of treated wastewater discharge on the river EC depends on the relative flows (i.e., dilution) and the difference between the effluent EC and the river EC (i.e., excess EC). The dilution of a river discharge is often expressed as the ratio of the river flow to the effluent flow. The fraction of effluent in downstream river water would be estimated as 1/ (dilution +1). For example, if river flow is 4 times the discharge, the dilution is 4 and downstream concentrations will be 1/5 of effluent concentrations (assuming the upstream river concentrations of the constituents are zero). The EC change downstream of the discharge can be calculated as:

(Eqn. F.2-1):

EC Change = (Discharge EC – River EC) x Discharge / (River flow + Discharge) = Excess EC / [Dilution + 1]

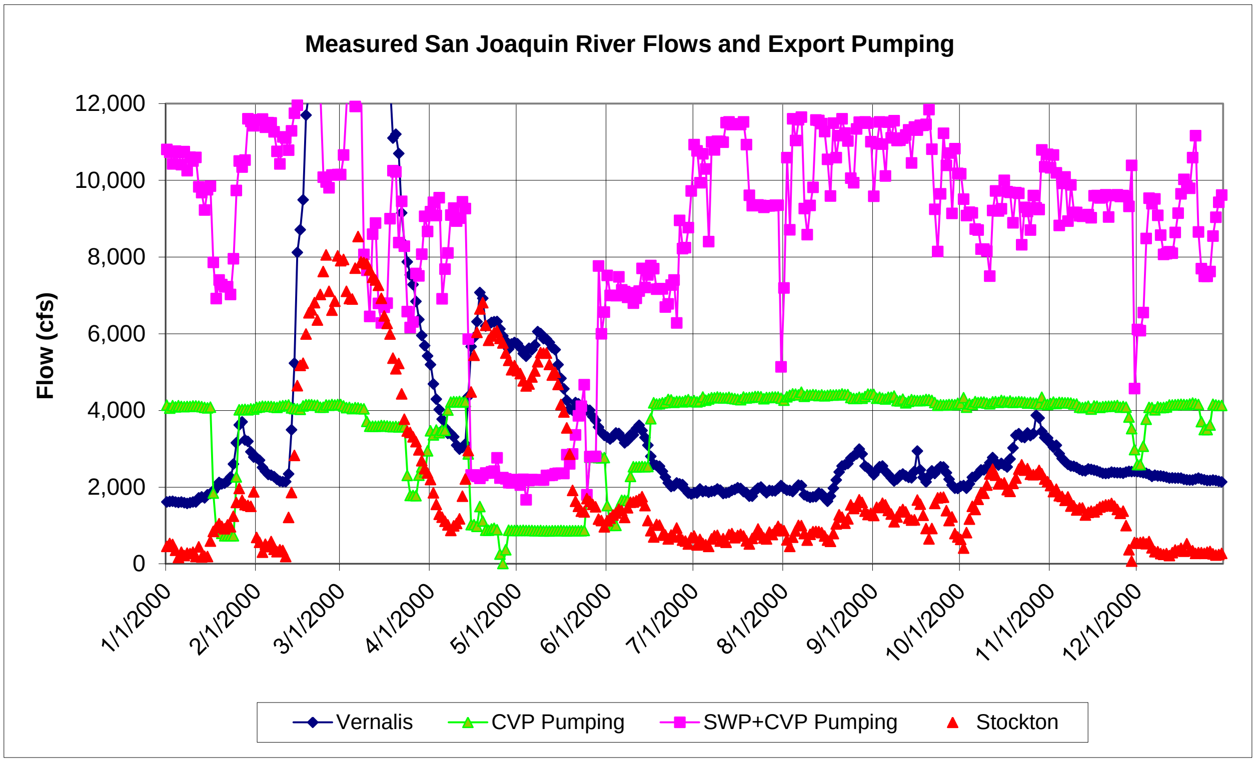
These equations can be used to determine how much discharge can be added to a river without causing a violation of EC standards. Low river flow with high EC provides little assimilative capacity for discharges. For example, if Vernalis EC in April is at 700 µS/cm, the San Joaquin River would have no assimilative capacity and the only way that a discharge could maintain river EC below the Bay-Delta Plan objective would be for the discharge to be at or below the 700 µS/cm objective. In contrast, if the SJR EC is at 600 µS/cm, there would be some assimilative capacity. For example, if river flow was 970 cfs and a discharge was 30 cfs with an EC of 1,500 µS/cm, the increase in river EC associated with the discharge would be 27 μS/cm and SJR EC would remain below the 700 μS/cm objective (i.e., [1500 μS/cm -600 μS/cm]/[970 cfs/30 cfs+1])

F.2.4.3 Daily Delta Flows and EC Data for 2000

Figure F.2-6a shows the measured flows and export pumping in calendar year 2000. The estimated flows at the head of Old River (diluting the City of Tracy discharge) and in Old River at the Tracy Boulevard Bridge (diluting the Mountain House discharge) are shown in the lower panel. The head of Old River flow can be calculated as the difference between the Vernalis flow and the measured Stockton flow (Garwood Bridge). The Old River flow at the Tracy Boulevard Bridge has been estimated as 10 percent of the head of Old River flow, based on DSM2 tidal hydraulic modeling results and recent tidal flow measurements. The majority of the flow moves down Grant Line Canal toward the CVP and SWP pumps.

Vernalis flow in 2000 was about 2,000 cfs in January and increased to about 15,000 cfs during the major storm runoff event in late February and March. The Vernalis flow had declined to about 3,000 cfs when the flow was raised during VAMP to about 6,000 cfs from April 15–May 15. Flows declined to about 4,000 cfs at the beginning of June and were 2,000 cfs from the end of June until the end of the year. A pulse flow release to attract adult Chinook salmon increased flows in the second half of October to about 3,000 cfs.

The bottom panel of Figure F.2-6a shows the flows measured at Stockton in 2000 were less than 50 percent of the Vernalis flow (i.e., the normal flow split) because high CVP and SWP export pumping (i.e., lower tidal elevations) shifted more SJR flow into Old River. The Stockton flows were about 500 cfs less than the Vernalis flows during VAMP when the head of Old River barrier was installed, and during October and November when the fall barrier was installed. The estimated flow at the Head of Old River can be compared to the calculated Vernalis flow minus Stockton flow. The estimated flow through the barrier culverts of about 500 cfs was generally confirmed by the calculated values. The estimated Old River flows in summer appear to be greater than the calculated (Vernalis minus Stockton) flows.



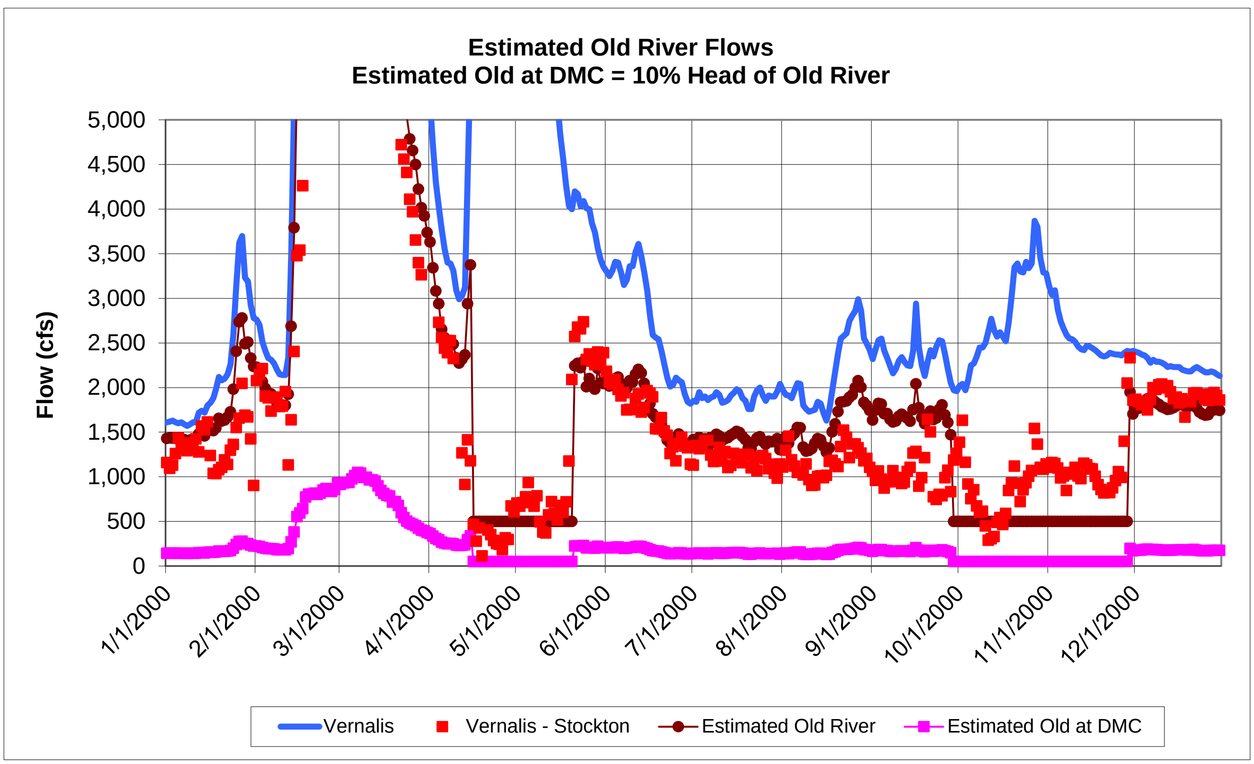
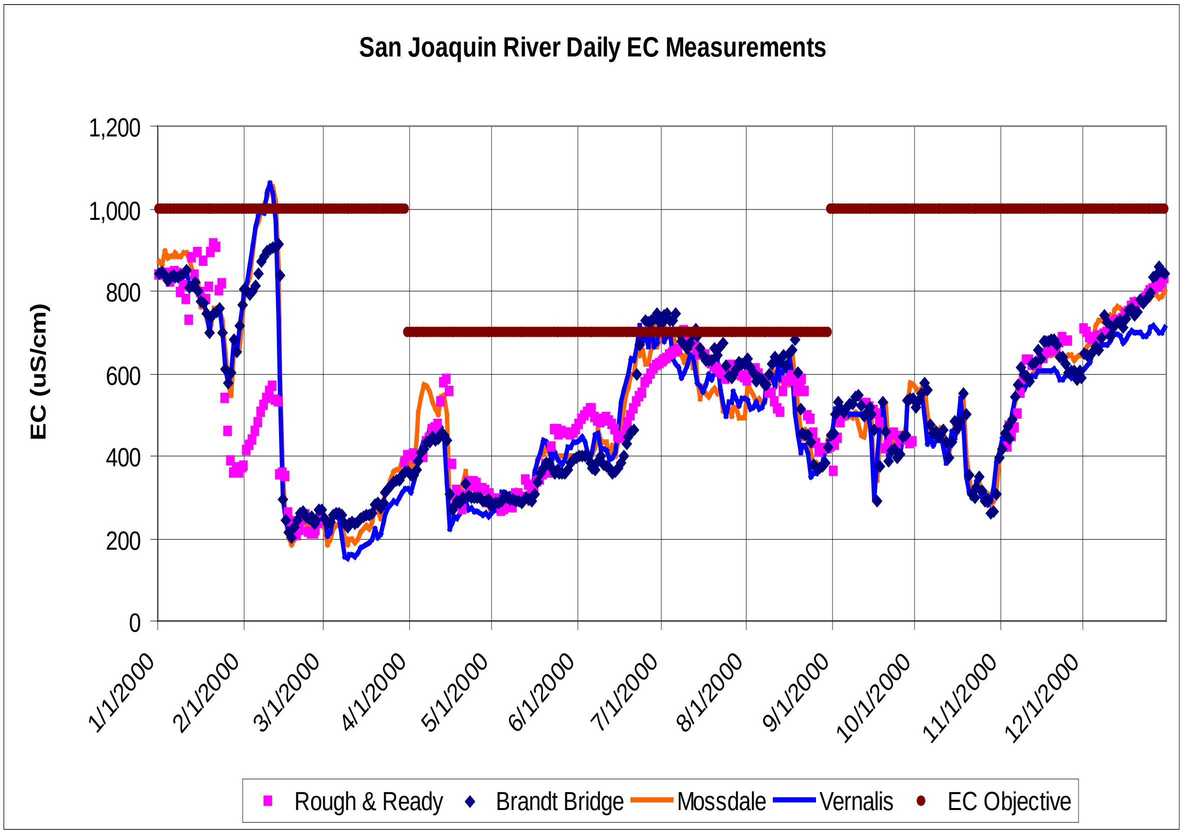


Figure F.2-6a. Historical Daily SJR Flows, CVP and SWP Export Pumping Flows, and Old River Flows for 2000

Figure F.2-6b shows the measured EC in the SJR and Old River during 2000. The four stations shown in the top panel are Vernalis, Mossdale, Brant Bridge, and Rough and Ready Island. The SJR EC was about 800 μS/cm in January and reduced to about 200 μS/cm during the large storm runoff period in February and March. The EC increased to 400 μS/cm in early April and reduced to 300 μS/cm during the VAMP flow of about 6,000 cfs. The EC reached 700 μS/cm at the end of June, then decreased slightly to 600 μS/cm in July and August, and was about 500 μS/cm in September and October. The Vernalis EC was about 600 μS/cm in November and approached 800 μS/cm at the end of December 2000. The EC values are expected to increase slightly at each downstream station from agricultural drainage and wastewater discharge at Lathrop and Stockton. However, EC values at each of four stations were very similar most of the time during 2000. Because the EC measurements are independently calibrated, some variation in measurements is expected. A measurement variation of about 25 μS/cm may be typical. Detecting difference of less than 25 μS/cm may not be reliable with these routine field measurements.

The bottom panel of Figure F.2-6b shows the EC along Old River. The Union Island station is just upstream of the Tracy discharge, and the EC values were similar to the Vernalis and Mossdale EC values. The Old River at Tracy Boulevard Bridge station EC values were similar to the Union EC values until August, but were higher than the Union EC values in September–December. The EC values at the DMC intake and at the SWP Banks pumping-plant were lower than the SJR EC values in January and throughout the summer months of June–September. The DMC and Banks EC values were similar to the SJR EC in October–December. The DMC and Banks EC values are influenced by Sacramento River EC (of about 200 μS/cm) and salinity intrusion from Suisun Bay in the fall when Delta outflow is generally reduced.



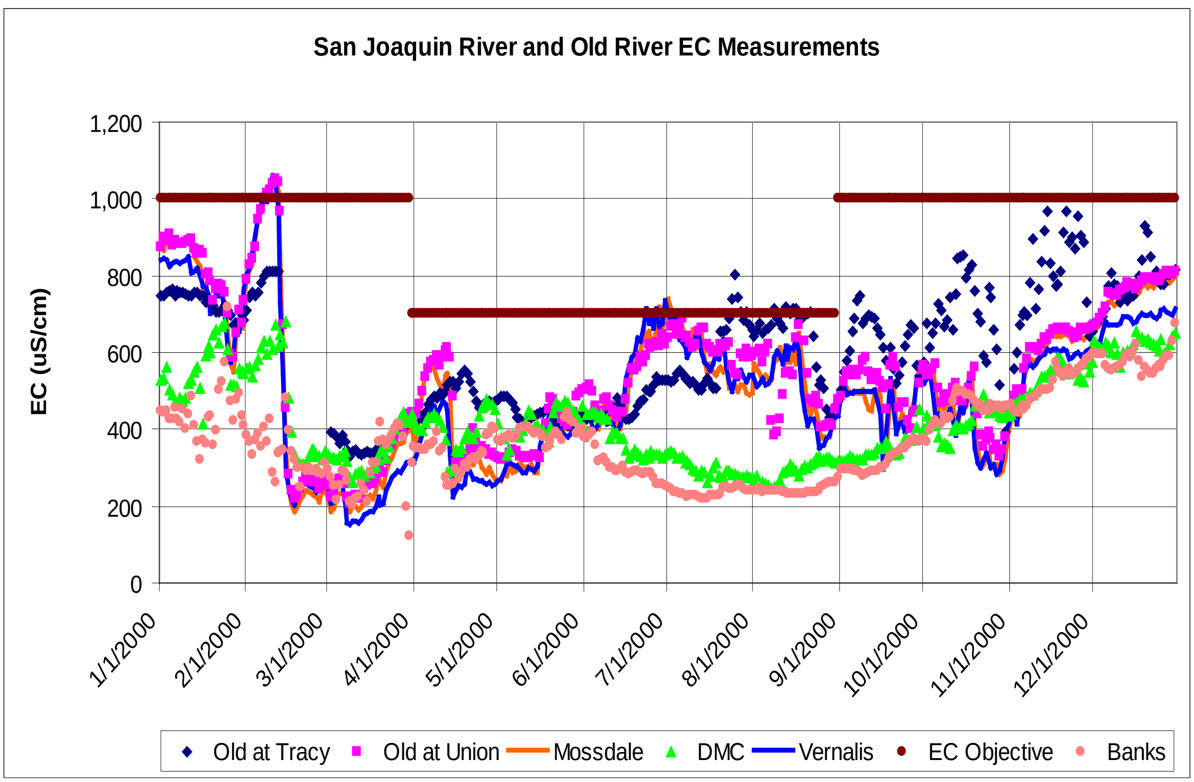
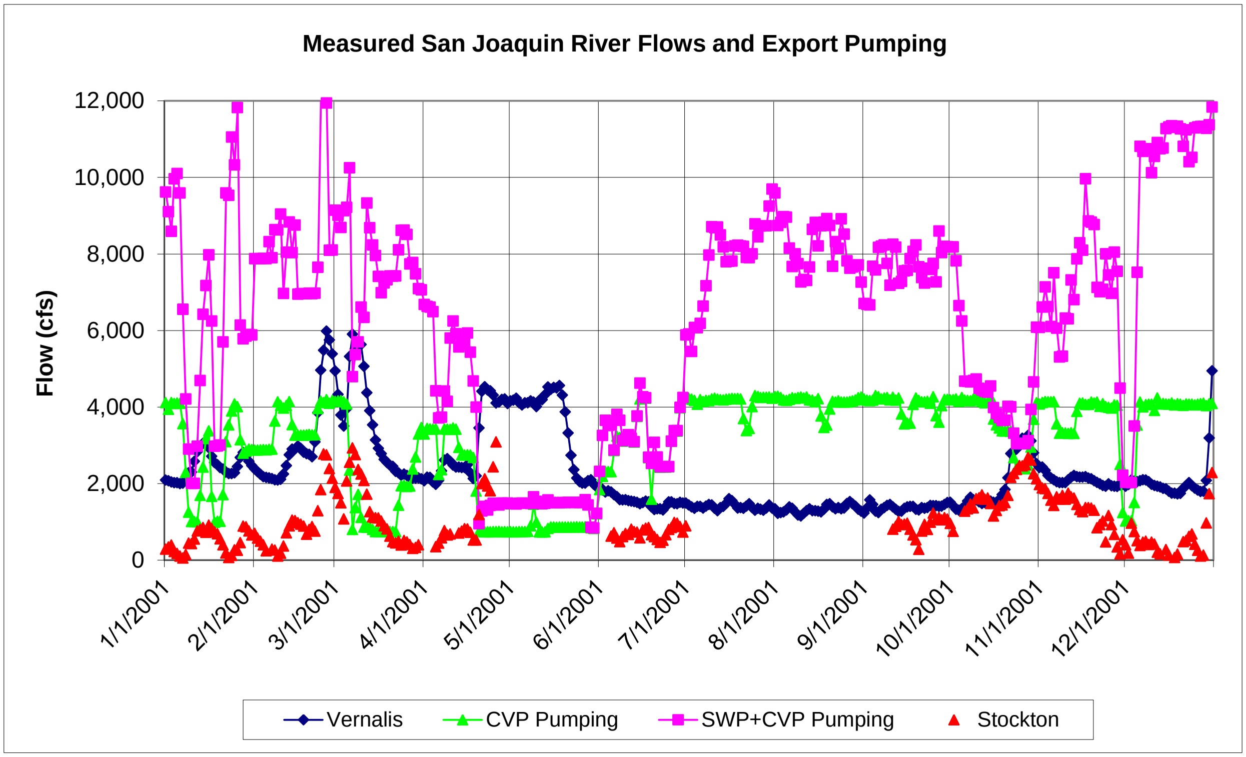


Figure F.2-6b. Historical Measured Daily EC in the SJR and Old River for 2000

F.2.4.4 Daily Delta Flows and EC Data for 2001

Figure F.2-7a shows the measured flows and export pumping in calendar year 2001. Vernalis flows in 2001 were about 2,000 cfs in January and February and increased to about 5,000 cfs during late February and early March. The Vernalis flow had declined to about 2,000 cfs at the beginning of VAMP, when the flows were raised to about 4,000 cfs from April 25 through May 25. Flows declined to about 2,000 cfs at the beginning of June and were 1,500 cfs from the end of June until mid-October. A pulse flow release to attract adult Chinook salmon increased flows in the second half of October to about 3,000 cfs. Flows were 2,000 cfs in November and December of 2001.

Flows measured at Stockton in 2001 indicate that less than 50 percent of the Vernalis flow reached Stockton during January–April, because the high CVP and SWP export pumping effects shifted more of the river flow into Old River. Stockton flows were higher during VAMP when the head of Old River barrier was installed, and during October and November when the fall barrier was installed. The USGS tidal flow meter at Stockton was out of service during the summer of 2001, but flows were assumed to be about 25 percent of Vernalis flows because Stockton flows are reduced by about 5 percent of the export pumping. Export pumping in 2001 was about 6,000–8,000 cfs in January–March, reduced in April–June (especially during VAMP), and was about 8,000 cfs in July–September. Pumping was greater than 10,000 cfs in December, and Stockton flows were reduced to less than 200 cfs.



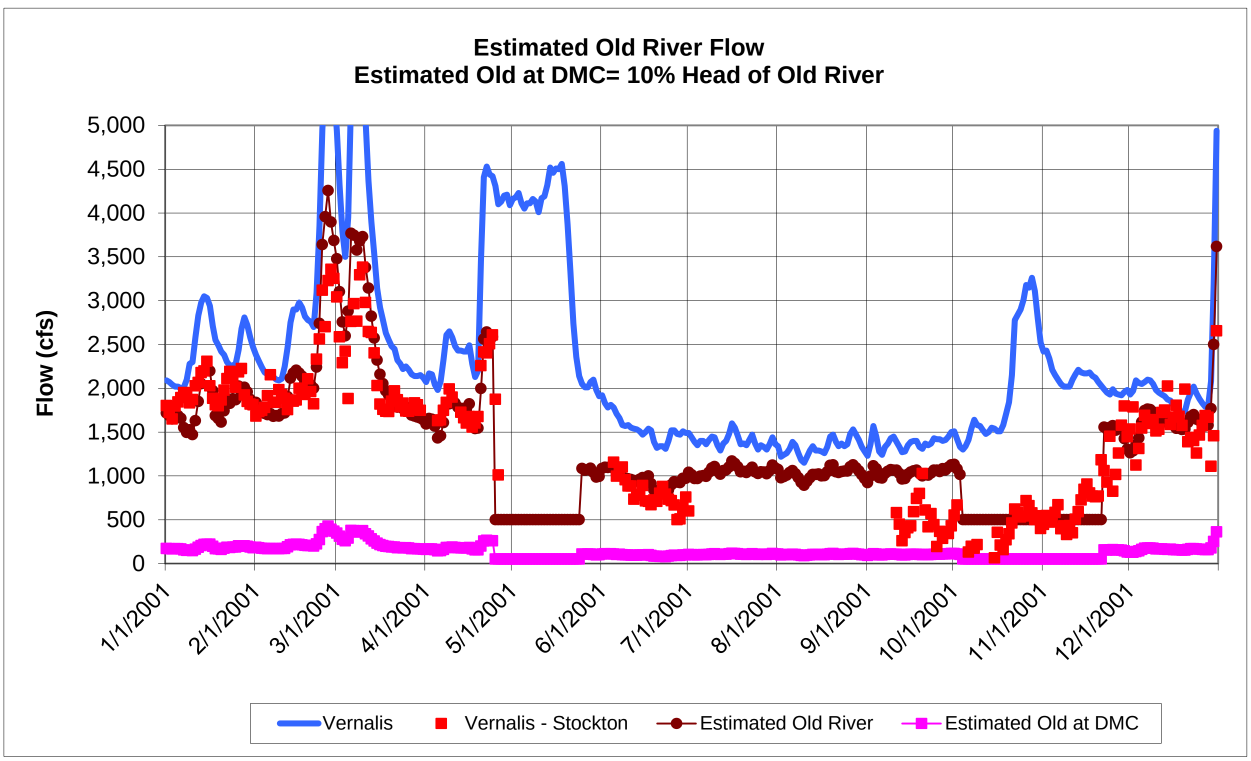
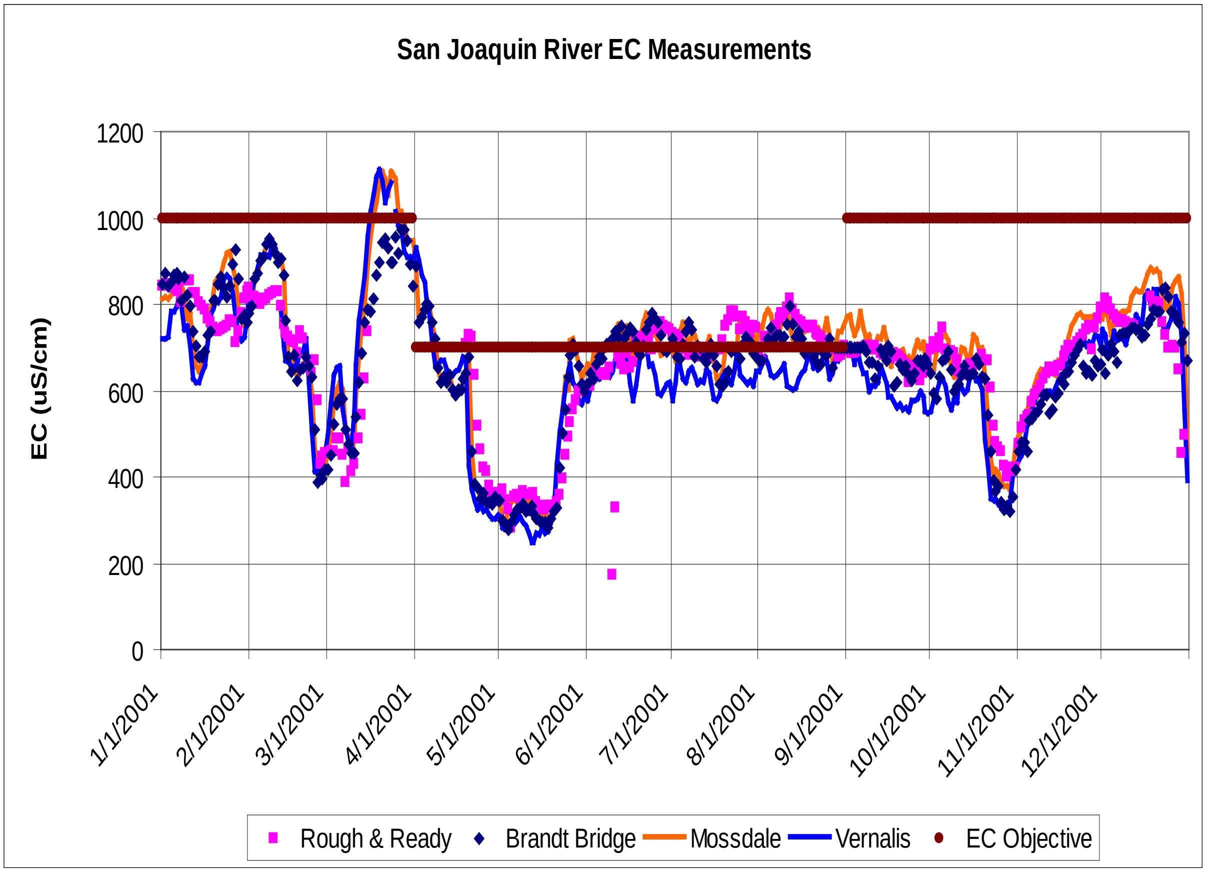


Figure F.2-7a. Historical Daily SJR Flows, CVP and SWP Export Pumping Flows, and Old River Flows for 2000

Figure F.2-7b shows the measured EC in the SJR during 2001. The measured SJR EC at all four stations was about 800 μS/cm in January and February and reduced to about 400 μS/cm during the runoff period in late February and early March. The EC increased to 1,000 μS/cm in late March but was reduced to about 350 μS/cm during the VAMP flow of about 4,000 cfs. The EC reached 700 μS/cm at the end of May and remained about 700 μS/cm through mid-October. The SJR EC was reduced to about 400 μS/cm during the late October pulse flow, but increased to 800 μS/cm by the end of November and December 2001. EC values at each of the four EC stations were very similar during most of 2001. The Vernalis EC was slightly lower than the other 3 stations during summer, suggesting the influence of downstream agriculture drainage and wastewater discharges.

The Old River at Union Island EC values were similar to the Vernalis EC and Mossdale EC values. The Old River at Tracy Boulevard EC was similar to the Union EC values until the VAMP period in May, when the EC at the Tracy Boulevard Bridge remained at 600 μS/cm, while the other EC values were reduced to 400 μS/cm. The Old River at Tracy Boulevard EC was 800–1,000 μS/cm from June–December, considerably higher than the SJR EC or Union EC. The EC values at the DMC intake and at the SWP Banks pumping-plant were lower than the SJR EC values in January–April and during June–August. The DMC and Banks EC values were lower than the SJR EC in November and December.



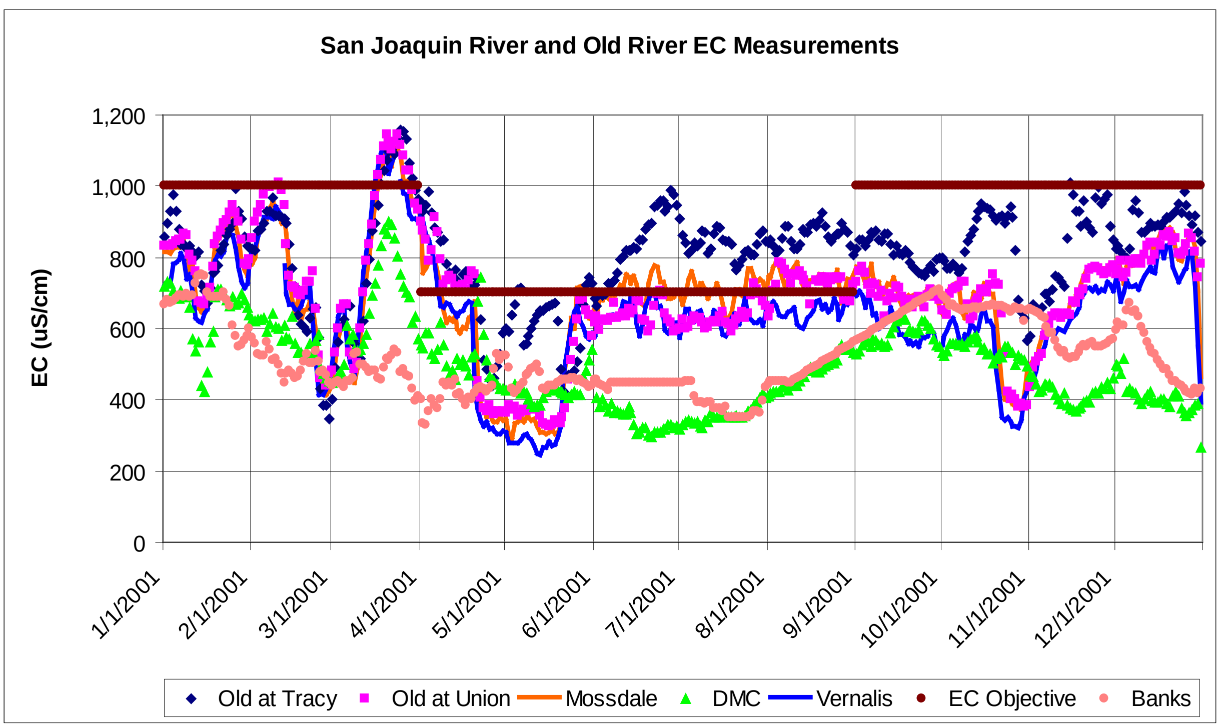


Figure F.2-7b. Historical Measured Daily EC in the SJR and Old River for 2001

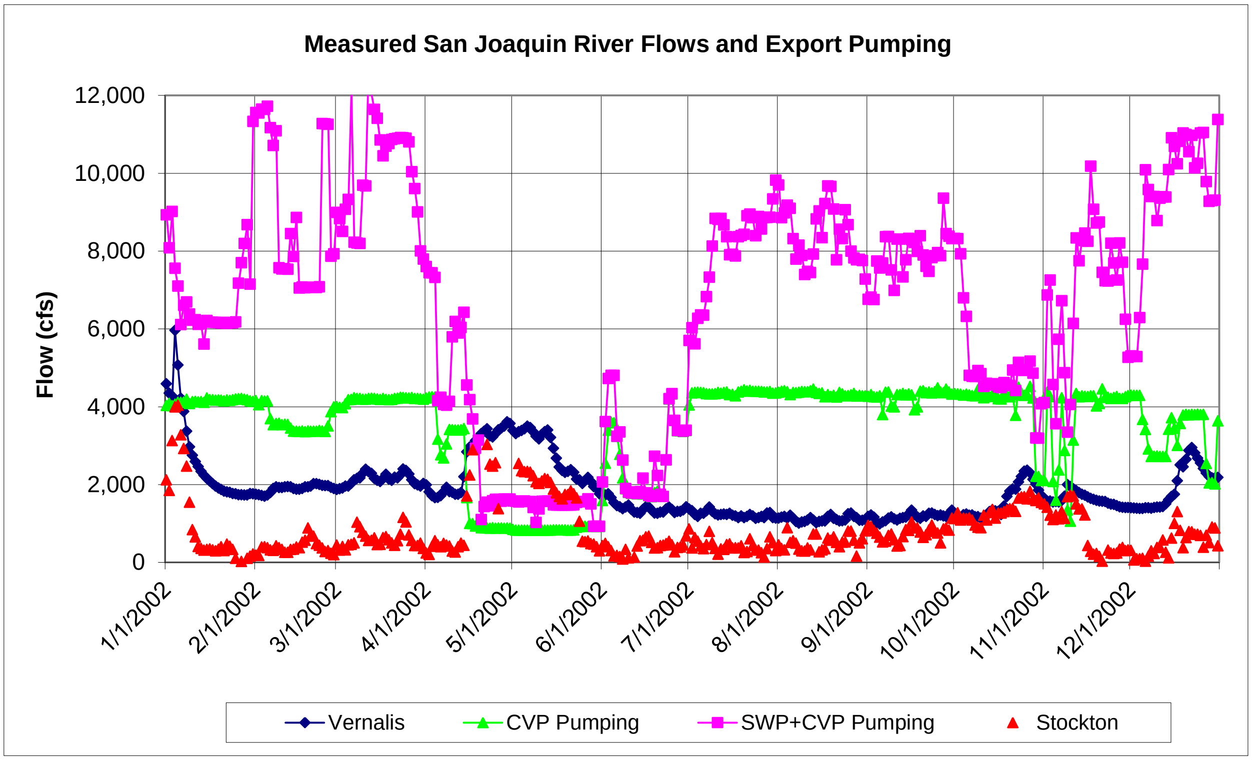
F.2.4.5 Daily Delta Flows and EC Data for 2002

Figure F.2-8a shows the measured flows and export pumping in calendar year 2002. The estimated flows at the head of Old River and in Old River at the Tracy Boulevard Bridge are shown in the lower panel. Vernalis flow in 2002 was about 4,000 cfs at the beginning of January but declined to 2,000 cfs at the end of January, and remained at 2,000 cfs until the VAMP period in mid-April. VAMP flow was about 3,500 cfs. Flows declined to about 2,000 cfs at the beginning of June and were less than 1,500 cfs from the end of June until the pulse at the end of October. Vernalis flows were a minimum of 1,000 cfs in August and September. Flows were about 1,500 cfs in November and increased to 2,000 cfs at the end of December 2002.

Export pumping in 2002 was about 6,000–12,000 cfs in January–March, reduced to less than 4,000 cfs in April–June (less than 2,000 cfs during VAMP), and was about 8,000 cfs in July–September. Pumping was just 4,000 cfs in October and then increased to about 8,000 cfs in November and 10,000 cfs in December.

Flows measured at Stockton in 2002 indicate much less than 50 percent of the Vernalis flow reached Stockton during much of the year, because of the high CVP and SWP export pumping. Stockton flows were higher during VAMP when the head of Old River barrier was installed and during October and early November when the fall barrier was installed.

The bottom panel of Figure F.2-8a shows the estimated Old River flows at the City of Tracy Discharge (similar to head of Old River flows) and at the DMC near the Mountain House discharge (Old River at DMC). The estimated head of Old River flows in August and September were greater than the Vernalis minus Stockton flows. As a result, the actual flows at the City of Tracy and Mountain House discharges were likely lower than the estimated flows during this period.



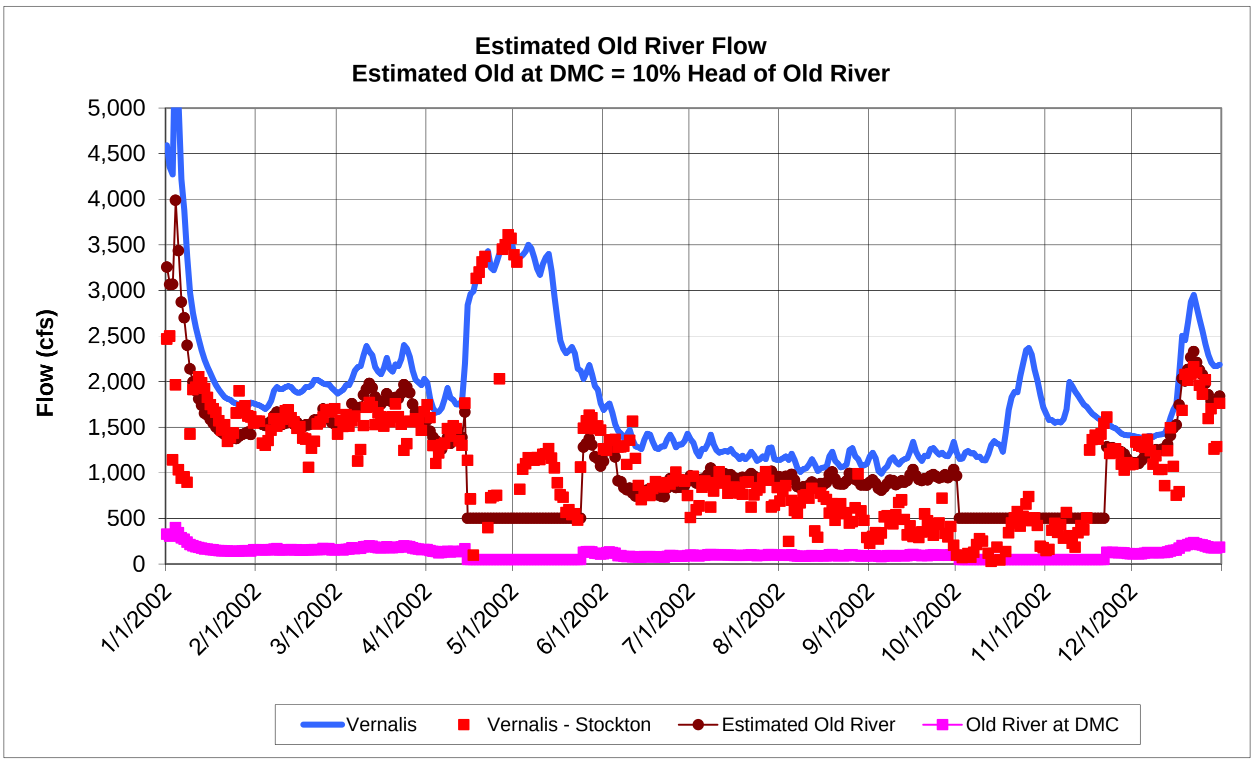
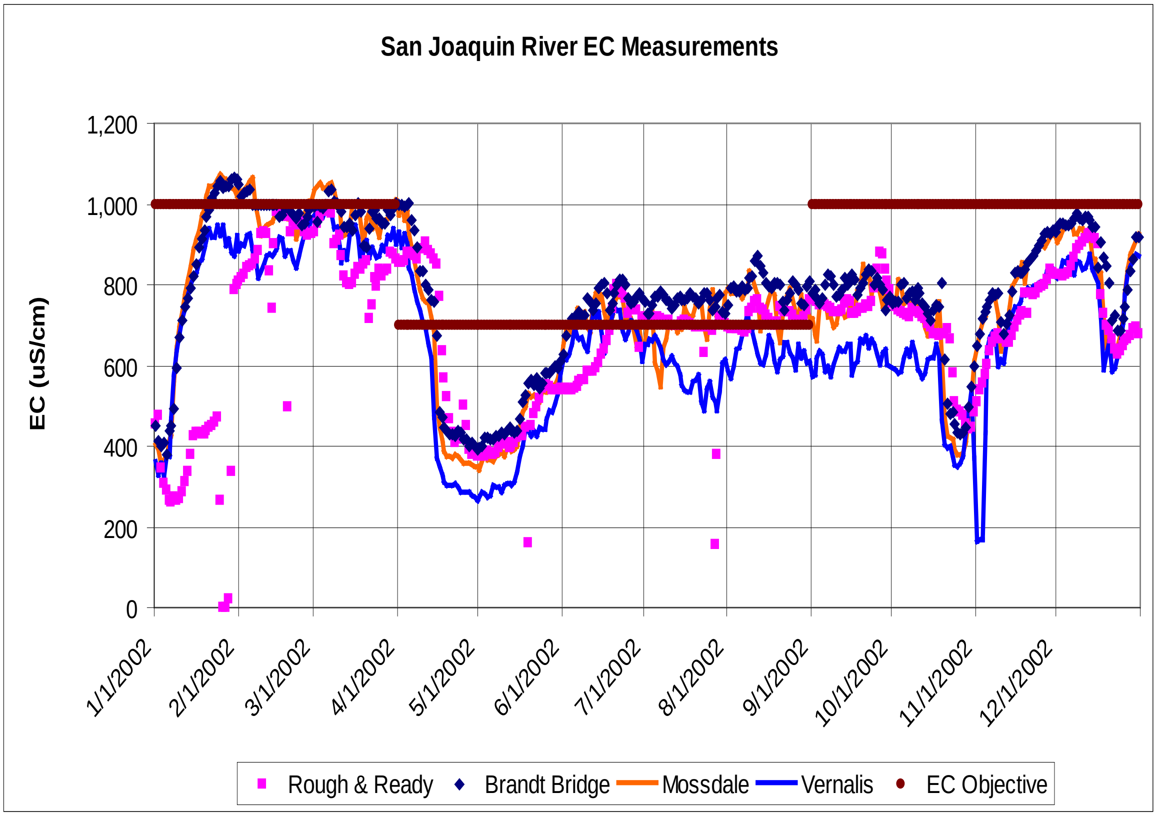


Figure F.2-8a. Historical Daily SJR Flows, CVP and SWP Export Pumping Flows, and Old River Flows for 2002

Figure F.2-8b shows the measured EC in the SJR during 2002. The Vernalis EC was about 100–200 μS/cm lower than the other three stations during most of the year. Because of these differences, it is difficult to determine the actual SJR EC values. The SJR EC was just 400 μS/cm during the early January storm but increased to 1,000 μS/cm in late January until VAMP. The EC was reduced to about 400 μS/cm during the VAMP flow of about 3,500 cfs. The EC reached 600 μS/cm at the end of May and was about 700 μS/cm from mid-June through mid-October. The Vernalis EC was reduced to about 400 μS/cm during the late October pulse flow, but increased to 800 μS/cm by the end of November, and was 1,000 μS/cm in December 2002. A small storm event diluted the EC to 600 μS/cm in mid-December 2002.

The bottom panel of Figure F.2-8b shows the EC along Old River in 2002. The Old River at Union EC values were similar to the Mossdale EC values. The Old River at Tracy Boulevard EC values were similar to the Union EC values until May, when the EC values at Tracy Boulevard increased to about 800 μS/cm. The EC at Tracy Boulevard was slightly higher than the EC at Mossdale or at Union. The EC values at the DMC intake and at the SWP Banks pumping plant were lower than the SJR EC values throughout most of 2002.



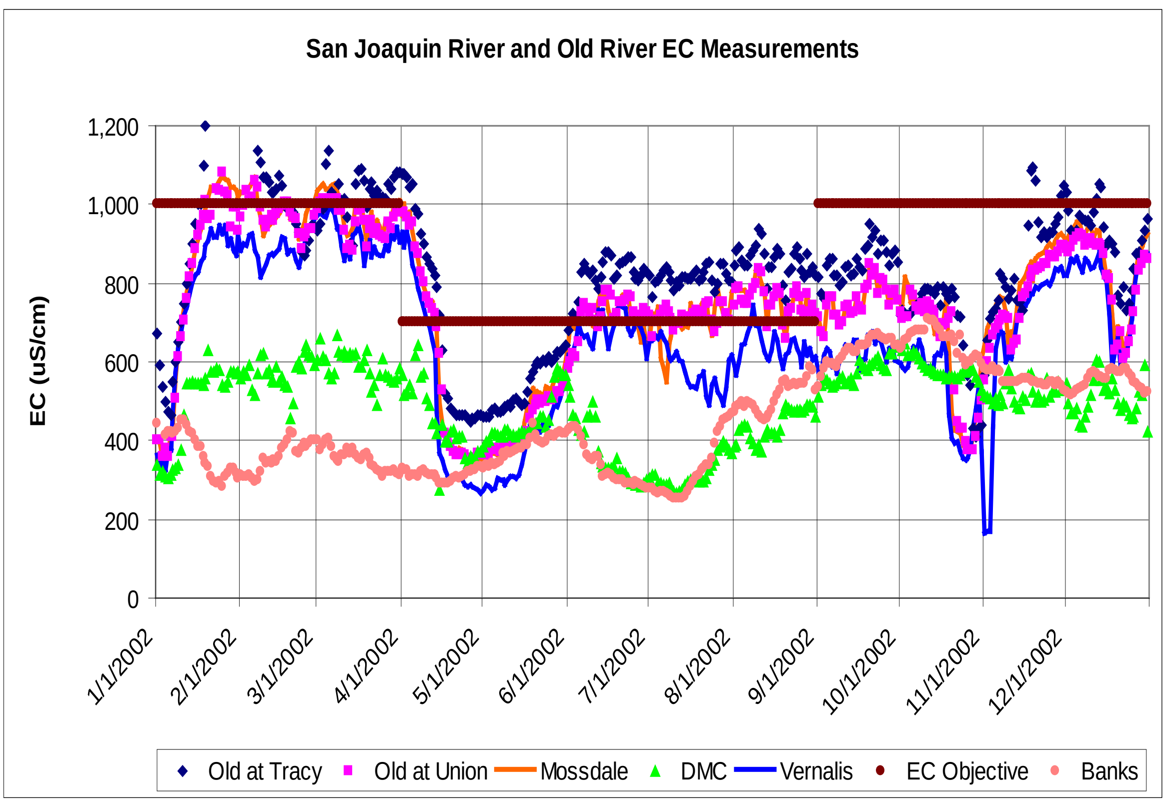


Figure F.2-8b. Historical Measured Daily EC in the SJR and Old River for 2002

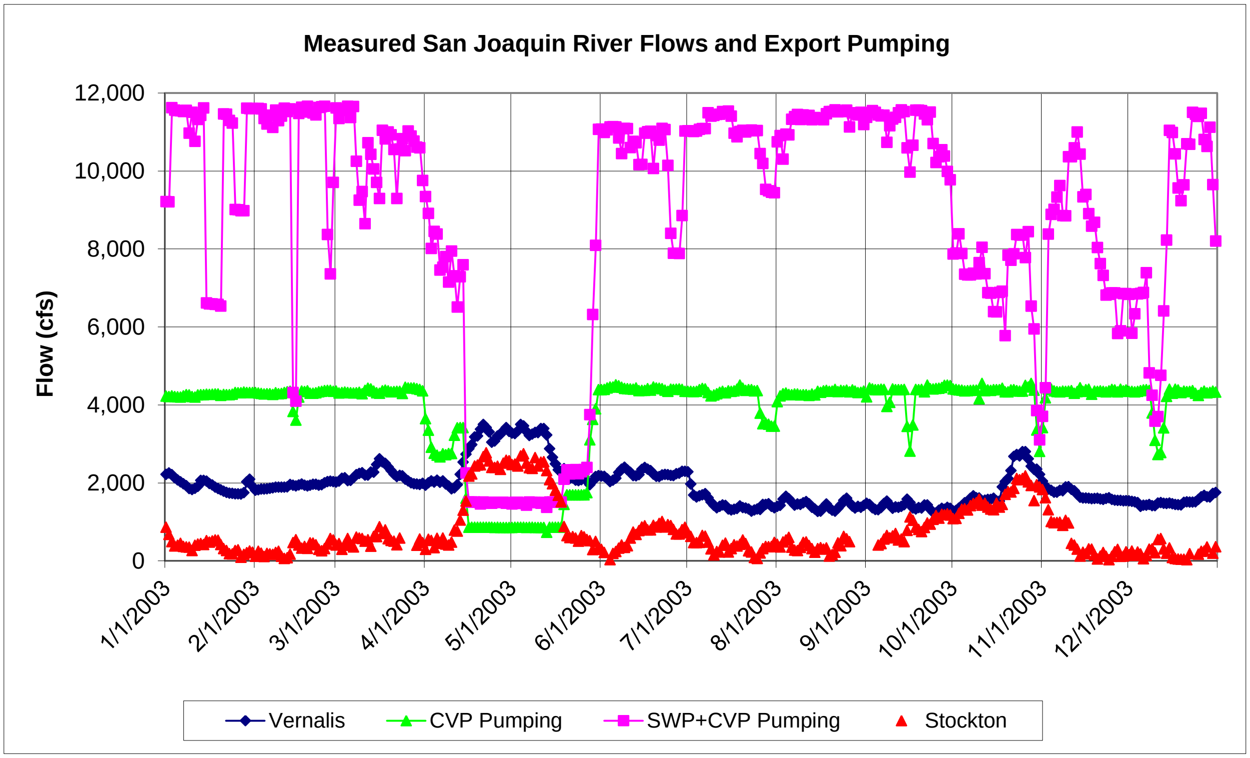
F.2.4.6 Daily Delta Flows and EC Data for 2003

Figure F.2-9a shows the measured flows and export pumping in calendar year 2003. The estimated flows at the head of Old River and in Old River at the Tracy Boulevard Bridge are shown in the lower panel. Vernalis flow in 2003 was extremely low with no major runoff events. Flow was 2,000 cfs from early January until the VAMP pulse in mid-April. The VAMP target was 3,500 cfs and the June flow was about 2,000 cfs. The summer flow was extremely low, with less than 1,500 cfs from July through mid-October when the fall pulse to attract chinook raised the flow to about 2,500 cfs in late October. Flows were just 2,000 cfs in November and December.

Export pumping in 2003 was generally high. CVP pumping was about 4,000 cfs all year except during April and May when reductions for fish protection were made. SWP pumping was near capacity of 6,680 cfs during most months, with reductions in April and May for VAMP and Environmental Water Account fish protections and in October–November. Total pumping was more than 10,000 cfs in January–March, June–September, and the end of December 2003.

Flows measured at Stockton in 2003 indicate less than 10 percent of the Vernalis flow reached Stockton during much of the year, because of the high CVP and SWP export pumping effects on the head of Old River diversions. The Stockton flows were higher during VAMP when the head of Old River barrier was installed, and during October and early November when the fall barrier was installed.

The bottom panel of Figure F.2-9a shows the estimated Old River flows at the City of Tracy discharge (similar to the head of Old River flows) and at the DMC near the Mountain House discharge. The estimated head of Old River flows matched the Vernalis minus Stockton flows. The Old River flows were greater than the assumed 500 cfs during the VAMP period and were less than the assumed 500 cfs when the fall barrier was installed.



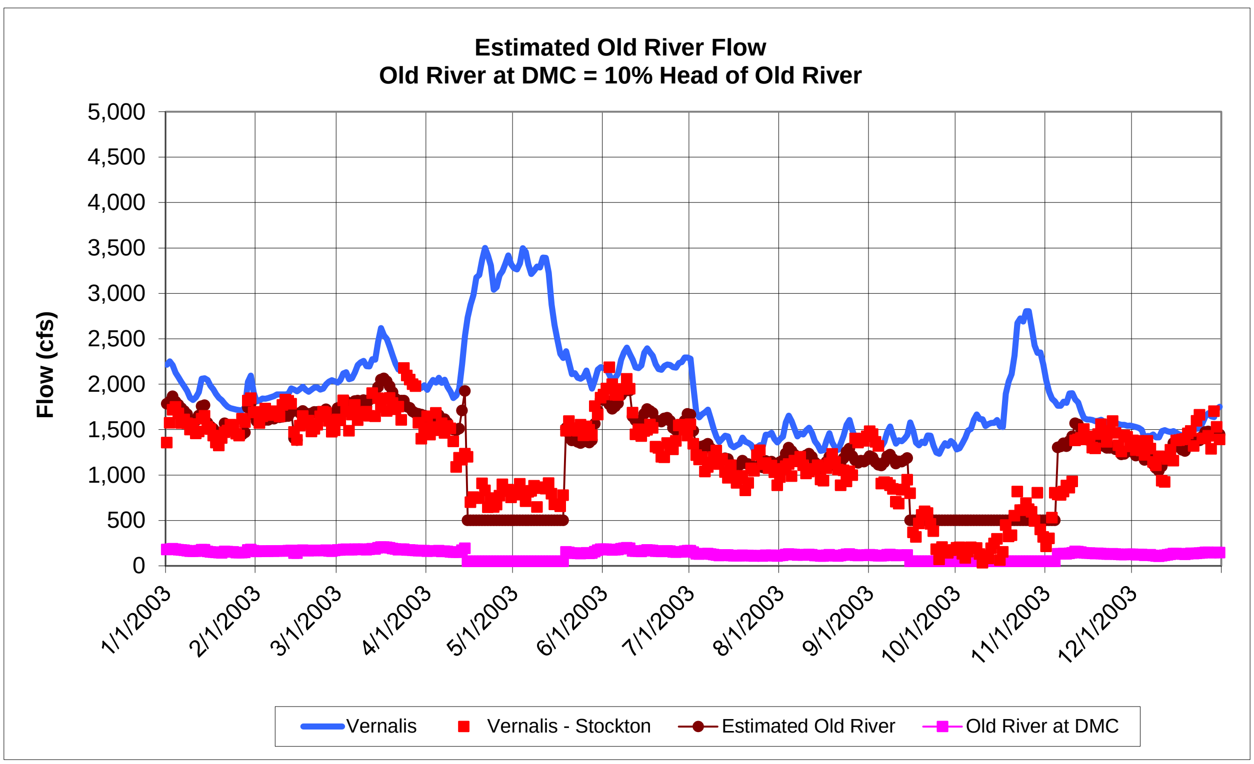
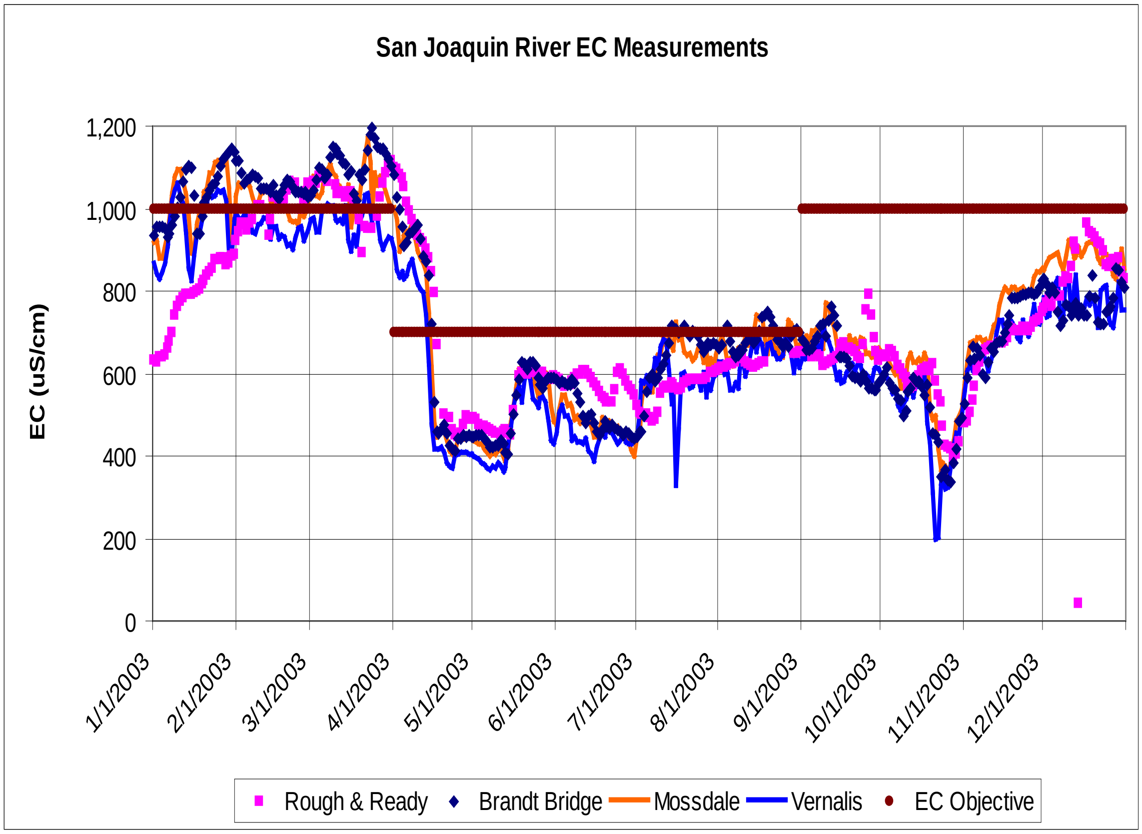


Figure F.2-9a. Historical Daily SJR Flows, CVP and SWP Export Pumping Flows, and Old River Flows for 2003

Figure F.2-9b shows the measured EC in the SJR during 2003. All four of the SJR EC stations recorded a similar pattern in 2003. The SJR EC was 900–1,100 µS/cm from January through March and reduced to about 400 µS/cm during the VAMP flow of about 3,500 cfs. The SJR EC reached 600 µS/cm at the end of May and remained at 600 µS/cm in June because the Vernalis flow was about 2,000 cfs through June. The EC increased to 700 µS/cm in July and August and decreased slightly to 600 µS/cm in September. The EC was reduced to about 400 µS/cm during the late October pulse flow but increased to 800 µS/cm by the end of November and in December 2003.

The bottom panel of Figure F.2-9b shows the EC along Old River in 2002. The Old River at Union EC values were similar to the Mossdale EC values. The Old River at Tracy Boulevard EC values were also similar to the Mossdale EC values throughout the year. This was in contrast to other years that indicated higher EC values at Tracy Boulevard. The EC values at the DMC intake and at the SWP Banks pumping-plant were much lower than the SJR EC values throughout all of 2003, except during the VAMP and late October pulse flows. The Banks EC values were lower than the DMC EC values in January–March but were nearly identical in May–December.



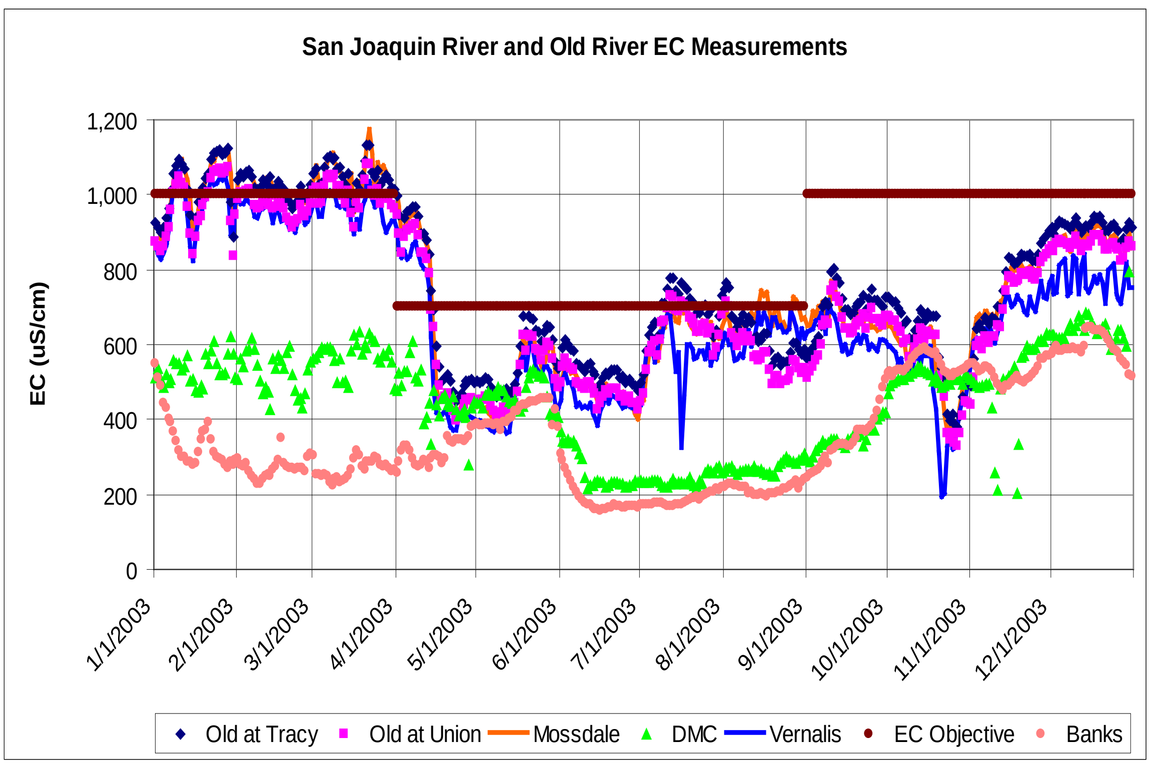


Figure F.2-9b. Historical Measured Daily EC in the SJR and Old River for 2003

F.2.4.7 Southern Delta Salinity (EC) Increments

Appendix C, *Technical Report On The Scientific Basis For Alternative San Joaquin River Flow And Southern Delta Salinity Objectives*, and the special study by DWR and USBR (USBR 2011) have suggested that the increased SJR EC downstream of Vernalis at Brandt Bridge, and in Old River at Union Island, as well as in Old River at Tracy Boulevard, can be generally estimated as a fraction of Vernalis plus a constant increase. Neither study was able to determine any other factor that could be shown to contribute to the patterns of measured EC increases between Vernalis and these downstream stations. However, an important possibility would be that the EC increases are caused by a somewhat constant monthly load of salt, so that the EC increases might be inversely related to the Vernalis flow. Evaluating the downstream EC as a function of the Vernalis EC and the Vernalis flow could provide a better tool for trying to attain EC compliance at the southern Delta stations (Brandt, Union, and Tracy). A graphical analysis of the monthly average EC data from 1985–2010 will introduce this approach.

Figures F.2-10a and F.2-10b show that the measured monthly Vernalis EC and the downstream southern Delta EC values (Brandt, Union, and Tracy) are generally reduced at higher flows. This effect of higher flow on reduced EC is apparent during both the agricultural irrigation season (April–August, EC objective of 700 μS/cm) and the non-irrigation season (September–March, EC objective of 1,000 μS/cm).

Figures F.2-11a and F.2-11b show the measured monthly EC increments from Vernalis to the downstream southern Delta stations. Although there is more scatter in these increments, and sometimes there are reduced EC values downstream, the EC increments are also generally reduced at higher flows. This effect of higher flow on reduced EC increments was observed during both the agricultural irrigation season and the non-irrigation season. Simple flow dilution relationships have been added to these data: the green line shows a flow dilution where the EC increment would be 100 μS/cm at a Vernalis flow of 1,000 cfs, the blue line shows a flow dilution with twice the EC increment (200 μS/cm at a flow of 1,000 cfs), and the red line shows a flow dilution with four times the EC increment (400 μS/cm at a flow of 1,000 cfs). All these increments are reduced to half at a flow of 2,000 cfs and are reduced to 20 percent at a flow of 5,000 cfs. More complicated estimates of the EC increments could be developed, but the Brandt Bridge and Union Island EC increments are well represented by the 100 μS/cm or the 200 μS/cm increment lines.

Because the Vernalis EC and the downstream EC increments are both reduced with higher Vernalis flow, control of the downstream EC will be possible with moderate increases in Vernalis flow in months when the Vernalis EC is approaching EC objectives and the downstream EC at Brandt or Union are above EC objectives. Attempting to reduce the EC increment at Tracy Boulevard Bridge with Vernalis flow will be more difficult; the EC at Tracy does not seem to be strongly related to the Vernalis EC or the Vernalis flow. If reduction of Tracy EC was attempted with Vernalis flow, much more Vernalis flow would be needed to reduce the Vernalis EC to Tracy EC increment.

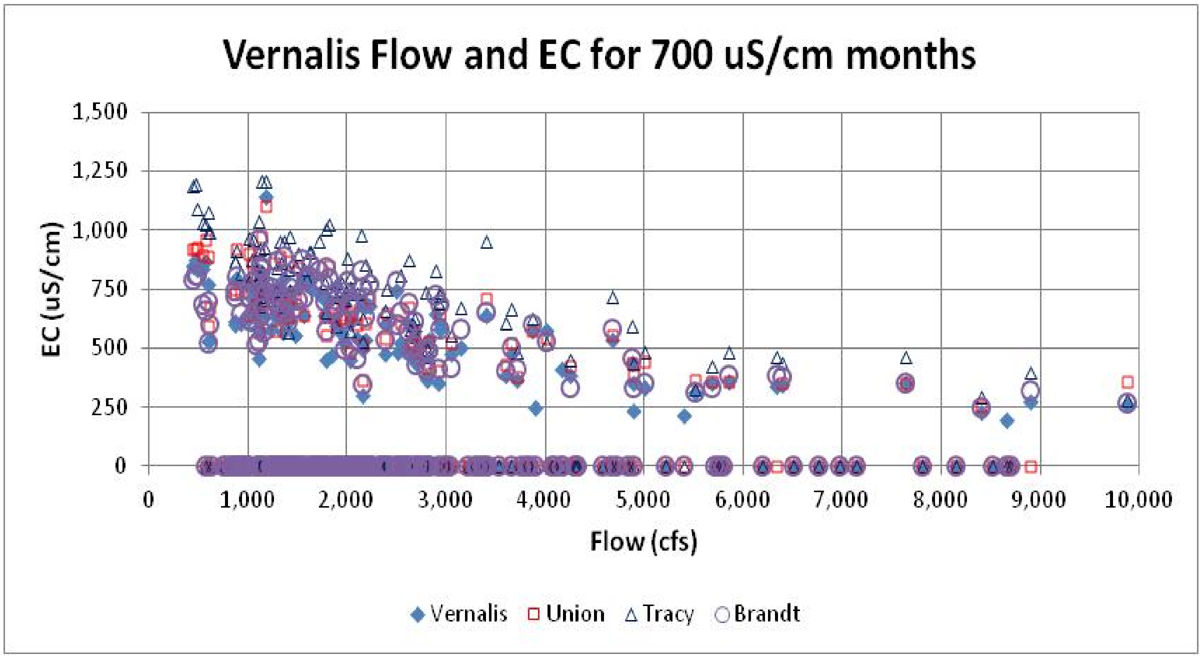


Figure F.2-10a. Monthly Average Vernalis Flow and Monthly Average Measured EC at Vernalis, Brandt Bridge, Union Island and Tracy Boulevard for April–August (700 µS/cm EC objective) of WY 1985–2010

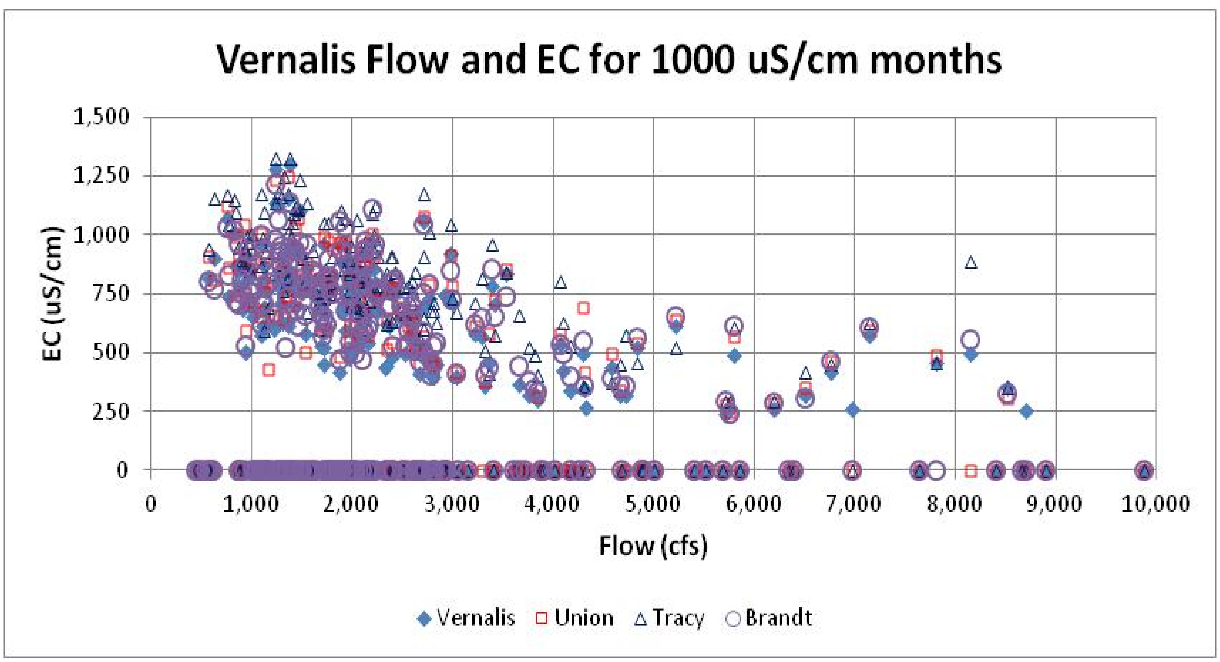


Figure F.2-10b. Monthly Average Vernalis Flow and Monthly Average Measured EC at Vernalis, Brandt Bridge, Union Island and Tracy Boulevard for September–March (1,000 µS/cm EC objective) of WY 1985–2010

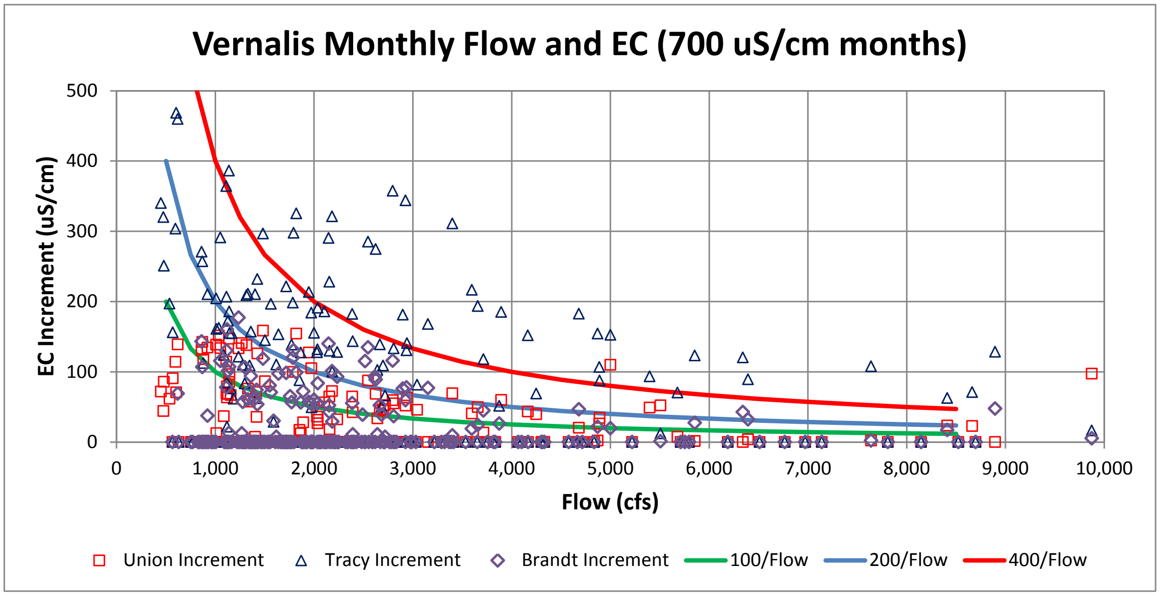


Figure F.2-11a. Monthly Average Vernalis Flow and Monthly Average EC Increments from Vernalis to Brandt Bridge, Union Island and Tracy Bridge for April–August (700 µS/cm EC objective) of WY 1985–2010

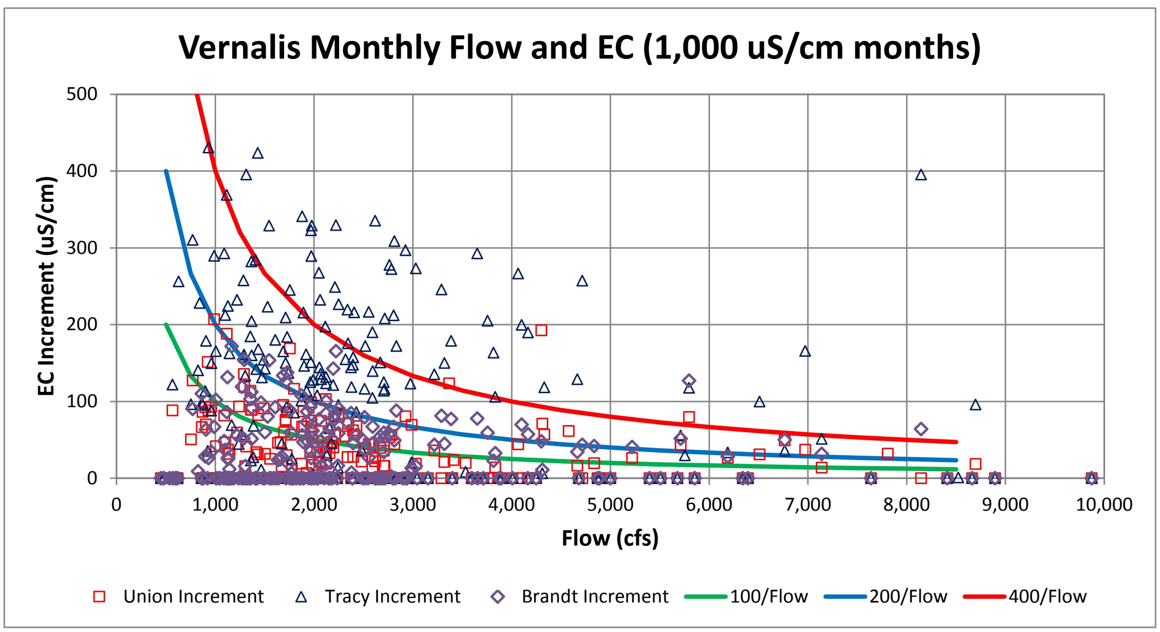


Figure F.2-11b. Monthly Average Vernalis Flow and Monthly Average EC Increments from Vernalis to Brandt Bridge, Union Island and Tracy Bridge for September–March (1,000 µS/cm EC objective) of WY 1985–2010

Figures F.2-12a and F.2-12b show the historical patterns of Vernalis flow and Vernalis EC as well as the southern Delta EC data for 1985–2010. The measured monthly EC at Vernalis has never exceeded EC objectives, and the southern Delta EC values have been higher than EC objectives in only a few months during the past 15 years (since 1995 when the Bay-Delta Plan specified the 700/1000 EC objective).

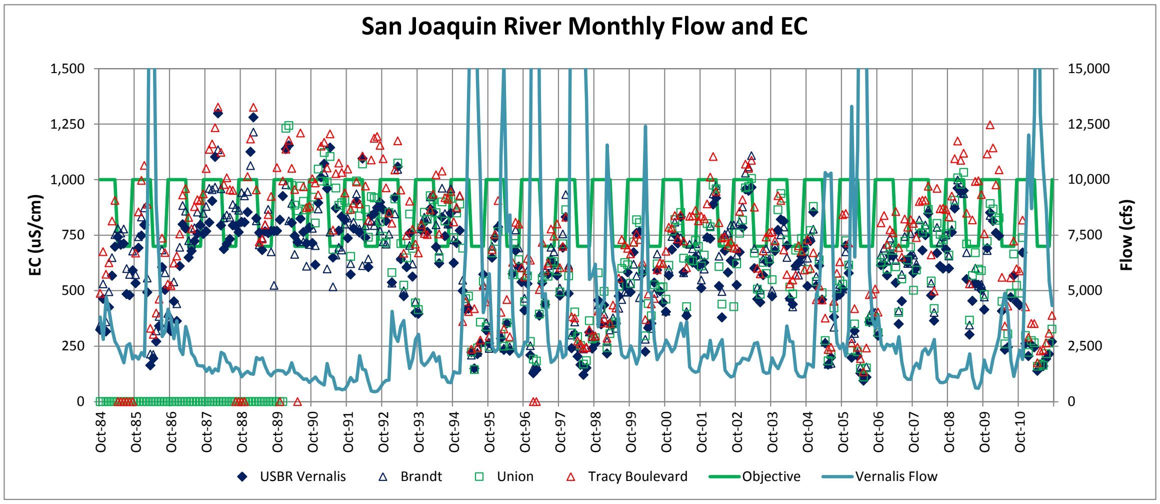


Figure F.2-12a. Monthly Average Vernalis Flow and Monthly Average Measured EC at Vernalis, Brandt Bridge, Union Island and Tracy Bridge for WY 1985–2010

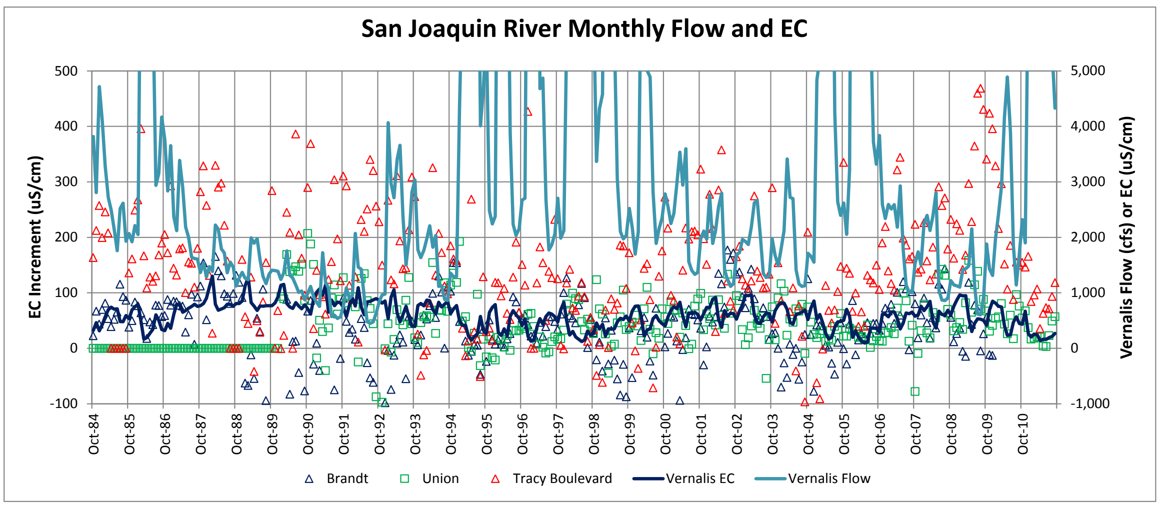


Figure F.2-12b. Monthly Average Vernalis Flow and Monthly EC Increments from Vernalis to Brandt Bridge, Union Island and Tracy Bridge for WY 1985–2010

F.2.4.8 Increased Stanislaus Flows for Southern Delta EC Compliance

An SJR at Vernalis EC buffer is needed to keep the SJR at Brandt Bridge EC or Old River at Tracy Boulevard EC less than the southern Delta EC objective. The EC buffer is equal to the calculated EC increment to Brandt Bridge or Tracy Boulevard. A review of historical EC data has suggested that the EC increment from Vernalis to Brandt Bridge or Tracy Boulevard can be estimated as:

$$\text{Brandt EC Increment } (\mu S/cm) = 100{,}000/\text{Vernalis Flow (cfs)}$$

$$\text{Tracy Boulevard EC Increment } (\mu S/cm) = 300{,}000/\text{Vernalis flow (cfs)}$$

The needed reduction in the Vernalis EC (if any) can then be calculated as:

$$\text{Vernalis EC Reduction} = \text{Vernalis EC} - \text{EC objective} + \text{EC Increment (buffer)}$$

The amount of Stanislaus water needed to reduce the Vernalis EC to provide the required buffer EC is:

$$\text{Stanislaus flow for EC buffer (cfs)} = \text{Vernalis flow} \times \text{Vernalis EC reduction} / (\text{Vernalis EC} - \text{Vernalis EC reduction} - \text{Stanislaus EC})$$

These equations can be rearranged to calculate the additional Stanislaus flow needed to meet the EC objective at Brandt Bridge or at Tracy Boulevard. These equations were used to estimate the additional Stanislaus flows for the No Action Vernalis flows and Vernalis EC values. It should be noted that an increase in Vernalis flow would slightly reduce the Brandt or Tracy Boulevard EC increment, which would mean that the Vernalis EC buffer needed to meet the objectives at Brandt Bridge and Tracy Boulevard would be slightly smaller than initially estimated and the calculated increase in flow needed to attain the desired EC buffer at Vernalis would be conservative (i.e., would be slightly more than needed). Although the EC increment for Tracy Boulevard is 3 times the Brandt Bridge EC increment, there are many times when the Brandt EC meets the EC objective but the Tracy EC will be greater than the EC objective. Therefore, much more Stanislaus flow will be needed for meeting the Tracy Boulevard EC objective. The most added water would be needed in months when the Vernalis EC is at the EC objective.

F.2.5 References Cited

Kratzer, C. R., P. J. Pickett, E. A. Rashmawi, C. L. Cross, and K. D. Bergeron. 1987. *An Input-Output Model of the San Joaquin River from the Lander Avenue Bridge to the Airport Way Bridge.* Appendix C of California State Water Board Order No. W.Q. 85-1 Technical Committee Report.

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